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DIVISION I

GENERAL REQUIREMENTS AND COVENANTS

1603 MATERIALS: SPECIFICATIONS, SAMPLES, TESTS, AND ACCEPTANCE

1603.1 SPECIFICATIONS

The Department will sample, test, and inspect all Materials in accordance with the Contract at any time before being permanently incorporated in the Work. The Department will approve or reject Materials based on the results of this sampling, testing, and inspection. The material requirements that describe material sampling, testing and inspection are normally referenced in Division II (construction details), the Plans, or the Special Provisions. In the absence of a specific material reference, the governing material specifications, in order of precedence, will be Division III (materials), AASHTO, ASTM, and the applicable industry standard.

Unless otherwise required, if the Contract cites specifications, standards, methods, tests, or practices from outside associations, societies, or governmental agencies, the Department is referring to the versions of these references that are current at the date of the Advertisement for Bids. If the Contract refers to other procedures, practices, or allowances established or approved by the Department, the Department will refer to the versions of these references that are current at the date of the Advertisement for Bids. The Department and Contractor may mutually agree to update the referenced provisions to the version current at the time of application.

1603.2 SAMPLING AND TESTING

Refer to the Schedule of Materials Control for sampling and testing of Materials on State and Federal-aid Projects. The Schedule of Materials Control sets the size of Material samples and the rate of testing. The Schedule of Materials Control does not set Contract requirements for the Material. The Schedule of Materials Control is included with the Proposal Package.

The Contractor shall provide all required samples at no additional cost to the Department and shall provide such facilities and assistance as the Engineer directs for collecting and forwarding samples. If required by the Engineer, the Contractor shall submit representative preliminary samples to the Engineer in accordance with the specified methods, for examination and testing. The Contractor shall label submitted preliminary samples with the following information:

- (1) Contractor's name,
- (2) Project number,
- (3) The material source,
- (4) Supplier's name, and
- (5) Where the material fits into the Work.

For soil and aggregate samples, the Contractor shall provide the following additional information:

- (1) The legal description of the property where the samples were taken, and
- (2) Pit numbers for single source bituminous and concrete aggregate products.

The Department will provide special instructions for sampling upon request from the Contractor.

1603.3 CERTIFICATE OF COMPLIANCE

The Engineer may accept industry standardized products by a Certificate of Compliance in lieu of the required sampling and testing, subject to the following:

- (1) The Certificate of Compliance must state that the provided Material meets the specification requirements, identify the Specification number, and include the Project number.
- (2) Attach the Certificate of Compliance to the invoice, weigh bill, or other shipping document, and identify the supplier, manufacturer, product, and quantities covered.

- (3) Deliver a copy of the Certificate of Compliance with the shipment of the covered Material.
- (4) Provide certified test reports to the Materials Engineer if requested. Keep certified test results on file with the supplier and available to the Engineer for inspection upon request.
- (5) The Certificate of Compliance must be signed by a representative authorized to bind the company supplying the material covered by the certification.

The Department may require samples and test the Material for compliance regardless of prior certification by the supplier.

When the Contractor uses a Certificate of Compliance in lieu of required sampling and testing, the Engineer will withhold 100 percent of the Contract Unit Price of Work until the Contractor submits the Certificate of Compliance to the Engineer.

1603.4 ACCEPTANCE

Department approval of preliminary samples will not constitute acceptance of the Material represented.

The Department will only consider the Materials actually delivered to the Project for acceptance. The Department will base Material acceptance or rejection on the results of the tests and inspections made by the Engineer. The Engineer will make final inspection and acceptance of Material at the Project.

The Department will not allow use of Material that must meet definite Contract requirements until completion of all required acceptance inspections and tests show the Material complies with the Contract requirements.

Pending determination of test results, the Contractor may use Material having a satisfactory record of compliance with the test requirements at the Contractor's risk, with the understanding that the Department will apply the provisions of 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work," if the material fails to meet the Contract requirements subsequent to placement.

1604 PLANT INSPECTION — COMMERCIAL FACILITY

1604.1 GENERAL

The Engineer may perform plant inspection and test Material at the source before delivery to determine compliance with those test requirements and process controls required by the Contract during production. The Engineer may retest Material at the site regardless of approvals given before final inspection and acceptance. The Engineer will base Material acceptance on compliance with Contract requirements at the time of incorporation in the Work.

The Engineer may retest Material after delivery and will reject Material that fails to meet the Contract requirements.

The cost of facilities and assistance provided by the Contractor required for inspection of Materials at the source will be considered as part of the production costs and are included in the Contract Unit Prices applying to the work involved.

1604.2 INSPECTION PROCEDURES

The Contractor shall meet the following conditions when the Engineer performs a plant inspection:

- (1) At least 2 weeks before starting production, notify the Engineer of the date and place of production to allow for arrangements for the plant inspection;
- (2) Notify the Engineer of the production schedule and other related information concerning inspection arrangements;

- (3) In partnership with the producer, cooperate with and assist the Engineer in the inspection. The Department's inspectors will not handle the Materials being inspected;
- (4) Arrange, store, and handle the Material as directed by the inspector;

- (5) Provide the Engineer with office space as defined in 1604.3, "Requirements For Facilities," at commercial production plants and other facilities, tools deemed necessary for inspection, and free entry to the plant locations where manufacturing or production occur; and
- (6) Provide and maintain safety measures as approved by the Engineer. The Engineer will terminate inspection at the source if conditions are deemed hazardous by the Engineer.

1604.3 REQUIREMENTS FOR FACILITIES

Commercial plants producing bituminous mixture, structural concrete, or graded aggregates for state Projects shall have in-plant inspection facilities meeting the following requirements:

- (1) Floor area of at least 120 sq. ft [11 sq. m], with weatherproof exterior construction, adequate natural lighting, and convenient accessibility.
- (2) Equipped with at least one suitable table or workbench, at least one stool and one chair, an approved fire extinguisher for use intended, and a suitable storage cabinet with lock.
- (3) Provided with adequate electric lighting and electrical outlets, adequate heating system, conveniently located sanitary facilities, and convenient access to running water supply.
- (4) Furnished with at least a 3-burner natural gas or electric stove for sample drying and with effective forced-air ventilation.
- (5) Provided with an electrically powered mechanical sieving apparatus to determine particle size distribution of fine aggregate (less than No. 4 [4.75 mm] sieve) capable of accommodating six full height No. 200 [75 μ m] round sieves with pan and cover provided by the Department. The Engineer will approve the apparatus after verifying that the sieving meets the requirements of AASHTO T 27.

The producer shall make the in-plant inspection facilities available to the Engineer before beginning production.

The producer shall maintain the in-plant inspection facilities until the termination of production, at no additional cost to the Department. If the facilities do not meet the requirements specified in this subsection, the Contractor shall provide an equivalent field laboratory unit at the plant site as directed by the Engineer and at no additional cost to the Department.

1605 SUBSTITUTE MATERIALS

When the Department classifies Material to be incorporated in the Work according to size, strength, type, or other design classification for separate units, courses, sections, or installations, the intent is to specify the acceptable level of compliance, quality, or service. The Contractor may provide Material exceeding the specified class, quality, service life, or other Contract requirements to facilitate the Work.

The Contractor may use substitutions only as approved by the Engineer, at no additional cost to the Department. The Engineer will establish the revised basis for acceptance in writing.

1606 STORAGE OF MATERIALS

The Contractor shall store Materials in a manner that preserves the quality and fitness of the Materials for the Work. The Department may inspect the stored Materials before use in the Work, even though the Department may have approved the Materials before storage. The Contractor shall store Materials to facilitate inspection.

The Contractor may use portions of the Project Site approved by the Engineer for storing Materials and for placing plant and Equipment. The Contractor shall provide needed additional space at no additional cost to the Department. The Contractor shall restore all portions of the Project Site used for storage or operations to acceptable condition, at no additional cost to the Department, before the Department will grant final acceptance of the Project.

The Contractor shall not use private property for storing Materials or Equipment without written permission of the owner or lessee. The Contractor shall provide the Engineer evidence of the written permission to use private property upon request.

The Department will only allow stockpiling of Materials within the Project Site that the Contractor will incorporate into the Work. This Specification applies to manufactured and natural Materials, including Materials stockpiled for crushing.

1607 HANDLING MATERIALS

The Contractor shall handle Materials to preserve quality and fitness for the Work. The Contractor shall transport Materials in vehicles constructed to prevent loss of Material after loading and measuring. The Contractor shall ensure the quantities of Materials as loaded are the same as the quantities received on the Project.

The Contractor shall use methods and Equipment to load and haul bulk Materials that prevent contamination or loss of Material after measurement and acceptance for the Work.

1608 UNACCEPTABLE MATERIALS

The Department considers Materials that do not meet the Contract requirements before being incorporated into the Work as unacceptable. The Engineer will reject unacceptable Material. The Contractor shall remove unacceptable Material from the Project, unless otherwise directed by the Engineer as allowed by 1603, "Materials: Specifications, Samples, Tests, and Acceptance."

If the Contractor corrects defects in Material that the Department determined was unacceptable and the Contractor brings the Materials into compliance with the Contract requirements, the Contractor may use the Material if authorized by the Engineer.

1609 DEPARTMENT-PROVIDED MATERIAL

The Department will deliver or make available Department-provided Material at the locations shown on the Plans or in the Special Provisions. The Contract Unit Price for the relevant Contract Items includes the costs of handling, transporting, and placing the Materials.

The Contractor shall take responsibility for Department-provided Material after the Department delivers or makes the Material available to the Contractor. The Department will deduct from moneys due the Contractor for shortages, deficiencies, or damage to the Material occurring after taking possession and for demurrage charges.

DIVISION II

CONSTRUCTION DETAILS

GRADING

2105 EXCAVATION AND EMBANKMENT

2105.1 DESCRIPTION

This work consists of excavating and placing embankment.

A Definitions

A.1 Road Core

The road core is the area below the grading grade to the bottom of the excavation and between the following:

- (1) For embankment heights ≤ 30 ft [10 m], from the grading grade point of intersections (P.I.s) with a 1:1 (V:H) slope and
- (2) For embankment heights > 30 ft [10 m], from the grading grade point of intersections (P.I.s) with a 1:1½ (V:H) slope.

A.2 Grading Grade

Grading grade is the bottom of the aggregate base.

A.3 Top of Subgrade

The top of the subgrade is the surface of material immediately beneath the granular material. If there is no granular layer, then the top of subgrade is the Grading Grade.

A.4 Optimum Moisture Content

The optimum moisture content is determined by the:

- Moisture Density Test Method (Proctor), or
- One-Point Proctor Method or
- Estimated Optimum Moisture Content Form (Form G&B-305).

A.5 Maximum Density

Maximum density is the maximum density determined by the Moisture Density Test Method (Proctor) test in the Grading and Base Manual.

A.6 Select Grading Material

Select grading materials are all mineral soils found in the Triaxial Chart in the Grading and Base Manual, excluding silt. Silt is defined as soils containing 80% or more silt-sized particles. Marl and organic soils are also excluded.

A.7 Granular Materials

Granular materials meet the requirements of 3149.2B1.

A.8 Non-Structural Grading Materials

Non-Structural grading materials are all mineral soils, excess topsoil, and organic soils, capable of supporting construction equipment.

A.9 Uniform Soils

Uniform soils have the same soil class per the Triaxial Chart in the Grading and Base Manual and have similar color, moisture content and performance characteristics.

A.10 Organic Soils

Organic soils contain ≥ 5 percent organic content.

2105.2 MATERIALS

A Excavation Material

The Engineer will classify the excavation using the following categories:

A.1 Common Excavation

Material not classified in any other category.

A.2 Subgrade Excavation

All excavation in the road core below the grading grade, exclusive of rock, muck, channel or rock channel excavation.

A.3 Rock Excavation

Material that requires drilling, blasting or ripping before excavation. This includes boulders and other detached rock larger than 1 cu. yd. [1 cu. m.].

A.4 Muck Excavation

The removal of organic soils as defined in 2105.1.A.10, "Organic Soils," and other unstable soils as designated by the plan, and below the natural ground level of marshes, swamps, or bogs, regardless of the moisture content. Muck excavation is limited to areas over which the roadway embankment or a structure is to be constructed.

A.5 Channel and Pond Excavation

Material from channel changes, waterways, and ponds outside of the roadway embankment not classified as rock channel excavation.

A.6 Rock Channel Excavation

Material classified as rock excavation from channel changes and waterways outside of the roadway embankment.

A.7 Blank

B Borrow Material

Provide borrow meeting the specifications in Table 2105-1.

Table 2105-1 Borrow Specifications	
Material	Specification
Common Borrow	2105.1A6, "Select Grading Material"
Granular Borrow	3149.2B1, "Granular Material"
Select Granular Borrow	3149.2B2, "Select Granular Material"
Topsoil Borrow	3877, "Topsoil Material"

Materials obtained by the Contractor from sources outside the roadway, must comply with 1601, "Source of Supply and Quality," and 1602, "Natural Material Sources."

Excess materials from within the excavation limits shown on the plans that meet the specified requirements can be used by the Contractor for borrow items shown on the plans. These excess materials must comply with 1405, "Use of Materials Found on the Project."

C Salvage Material

Salvage material is material available on the project that is saved for a specific use under the contract or future construction. Salvage of materials will be required only when there is a contract pay item in the plans.

D Stabilizing Aggregate3149.2.C

If the plans show a contract pay item for stabilizing aggregate, place stabilizing aggregate in accordance with 2211, "Aggregate Base".

2105.3 CONSTRUCTION REQUIREMENTS

A General

Road core embankment must be either select grading material per 2105.1A6 or granular materials per 2105.1A7.

Non-structural grading materials per 2105.1A8 may be used as embankment outside the road core.

All forms and the Grading and Base Manual are available on the Grading and Base Website. Unless otherwise designated, all test procedures are in the Grading and Base Manual.

Perform excavation and embankment operations within the plan excavation limits as required by the contract.

Before beginning excavation and embankment operations, comply with the requirements of 2101, "Clearing and Grubbing."

Maintain drainage in excavations and embankment operations at all times. Provide and maintain temporary drainage facilities until the permanent facilities are complete and operational. These requirements do not override the provisions of 1806, "Determination and Extension of Contract Time".

Provide and maintain temporary preparation and erosion control on embankment and stockpiles until finishing operations are complete.

Salvage and stockpile material within the right-of-way or at another location approved by the Engineer, if the contract has a pay item for salvage material.

Repair or replace settlement plates damaged by construction operations.

Protect structures during construction operations. Repair structures damaged by construction operations.

Materials containing recycled bituminous can only be placed in and above the road core, or used in base per 3138, "Aggregate for Surface and Base Courses".

B Contractor Quality Control (QC) Testing

Test according to the Schedule of Materials Control.

Test corrected areas that fail either QC or Verification Testing (VT).

B.1 Aggregate Certification

Certify granular materials on Form G&B-104 (*Certification of Aggregate and Granular Materials*). Attach all required aggregate test results to Form G&B-104.

Material placed without QC tests and certifications is unauthorized work in accordance with 1512, "Unacceptable and Unauthorized Work."

Perform the following QC tests during production:

- (1) Gradation,
- (2) Crushing,
- (3) Aggregate quality and
- (4) Bitumen content (using procedure 1852 or 1853 in the Laboratory Manual).

B.2 Moisture Control

Determine the optimum moisture content.

Test for the moisture content in areas that appear least likely to meet specifications.

Determine the moisture content during compaction using test methods listed in the Grading and Base Manual, or additional methods as approved by the Engineer.

Meet the moisture content requirements listed in Table 2105-2.

Table 2105-2 Moisture Content Requirements	
Minimum Compaction Requirements	Relative Moisture Content *
100 % of maximum density	65 % – 102 %
95 % of maximum density	65 % – 115 %
Quality Compaction	65 % – 102 %
Penetration Index Method	≥ 65 %
* As determined on form G&B-105	

Correct for moisture in areas represented by failing moisture tests before testing the compaction. Compaction tests taken in areas represented by failing moisture tests are not valid.

C Preparation of Embankment Foundation

Construct steps, before placing embankment material, at a minimum width of 12 in [300 mm] when slopes are steeper than 1:4 (V:H).

Ensure the foundation area drains freely.

Compact the bottom of the excavation according to Table 2105-3.

Table 2105-3 Required Compaction for Bottom of Excavation		
Excavation Depth Below Grading Grade *	Relative Moisture Content	Required Compaction
< 30 in [750 mm]	65% to 102%	Compact to 100% of maximum density
≥ 30 in [750 mm]	65% to 115%	Compact to 95% of maximum density or compact with 4 passes of a roller †
*: Excavation below the planned subgrade may be subject to 1402, "Contract Revisions" : An estimated value for the optimum moisture content may be used instead of determining this value using Form G&B-305. †: Roller must meet be adequate to compact lift thicknesses as placed. The Engineer may waive the four pass requirement, if the subgrade will not support the roller.		

Remove surfacing and excavate an existing road core in accordance with 2112, "Subgrade Preparation," or as required by the contract before placing embankments.

D Excavating Operations

Obtain the Engineer's written approval before excavating beyond the limits and elevations established by the contract.

Remove rock outcroppings from within the slope lines and to the elevations shown on the plans. Remove loosened rock from the backslopes. Provide drainage for the shoulder slopes. Do not leave undrainable depressions.

Presplit rock back slopes steeper than 1:1 (V:H). Control blasting operations to eliminate flying rock or debris.

Excavation below the planned subgrade to correct unstable conditions may be subject to 1402, "Contract Revisions"

E Placing Embankment Materials

Place embankments in uniform lifts, parallel to the Plan profile grade, over the full width of the roadway. Construct each lift of material using uniform soil.

Protect structures during placement of embankments.

Place granular materials in the uppermost portion of the subgrade, if it does not significantly change normal grading operations.

Excavate, stockpile, and place topsoil as required by the contract.

Obtain written permission from the Engineer before removing topsoil or granular material from the project.

Embankment materials placed on the road core may not increase the moisture content of the underlying material beyond the specified limits.

Non-granular materials placed above granular material must be at least 4 ft. [1.2 m.] thick.

Maximum lift thicknesses are controlled by the capability of the equipment to uniformly compact the entire lift in accordance with the following:

- (1) The Engineer will restrict lift thickness to no greater than 12 in [300 mm] (loose thickness), when uniform results are not achieved.
- (2) The Engineer may allow thicker lifts over saturated foundation soils. The top of the thicker lift must be at least 4 ft. [1.2 m] below the grading grade.

Uniformly blend the entire thickness of each lift before testing moisture content and compaction. Disc soils with greater than 20 percent passing the No. 200 [75 µm] sieve.

Stagger construction traffic uniformly over the full width of the roadway embankment.

Remove snow, ice, and frozen soils from road core before placing embankment.

2105-4: Use embankment material in the road core with particle sizes no larger than specified in Table

Table 2105-4 Maximum Particle Size in Road Core		
Depth from Grading Grade	Maximum Particle Size	
	Inches	mm
< 12 in [300 mm]	3	75
1 ft. – 3 ft. [300 mm – 900 mm]	6	150
3 ft. – 6 ft. [900 mm – 1,800 mm]	12	300
> 6 ft. [1,800 mm]	24	600
≤ 2 ft. [600 mm] from a structure	3	75
Areas where piling is to be placed	6	150

Remove surcharges as directed by the contract.

Install settlement plates, if required by the contract. Do not disturb settlement plates.

F Compacting Embankments

Maintain moisture content during compaction per Table 2105-2.

Correct the moisture in areas represented by failing tests before testing the compaction.

Compaction tests taken in areas represented by failing moisture tests are not valid.

Uniformly compact each lift of the road core:

- to the Specified Density requirements in 2105.3F1 for materials not meeting the requirements of 2105.1A7, “Granular Materials”.
- or to the Penetration Index (PI) requirements in 2105.3F3 for materials meeting the requirements of 2105.1A7, “Granular Materials”.

Compact all roadway embankment outside of the road core from 80 to 85 percent of the Maximum Density.

Compact the entire length and width of each lift with a roller. Construction traffic does not replace the rolling requirement.

Compaction requirements on swamp backfills start when the road core embankment is 4 ft. [1.2 m] above the water elevation at the time of construction operations.

The Engineer may waive mechanical compaction requirements on embankment containing predominately rock or topsoil.

Compact soils around structures with appropriate equipment or hand methods, to prevent damage to adjacent structures.

Correct or replace materials in areas represented by a failing test.

Maintain the required compaction until the next layer is placed.

F.1 Specified Density

Compact to meet the requirements of Table 2105-5.

Table 2105-5 Specified Density Requirements	
Embankment Location	Required Compaction (Relative Density)
≤ 3ft (1 m) Below Grading Grade of Road Core	100%
Within the Minimum of Either the Horizontal Distance Equal to the Full Height of a Structure or within 3 ft. of a Structure	100%
Remaining embankment in the road core	95%

F.2 Quality Compaction

Compact each lift until there is no further evidence of consolidation during compaction.

F.3 Penetration Index (PI)

Compact the entire lift to achieve a dynamic cone penetration index (DPI) value per Table 2105-6.

Table 2105-6 Maximum Allowable Penetration for DCP			
Grading Number †	Moisture Content ‖	Maximum Allowable DPI, mm/blow	Maximum Allowable Seat, mm
3.1 – 3.5	< 5.0	10	No Requirement
	5.0 – 8.0	12	
	> 8.0	16	
3.6 – 4.0	< 5.0	10	
	5.0 – 8.0	15	
	> 8.0	19	
4.1 – 4.5	< 5.0	13	
	5.0 – 8.0	17	
	> 8.0	21	
4.6 – 5.0	< 5.0	15	
	5.0 – 8.0	19	
	> 8.0	23	
5.1 – 5.5	< 5.0	17	
	5.0 – 8.0	21	
	> 8.0	25	
5.6 – 6.0	< 5.0	19	
	5.0 – 8.0	24	
	> 8.0	28	
† As determined by Form G&B-203			
‖ Percent of dry weight.			

G Agency Verification Testing (VT)

Test according to the Schedule of Materials Control.

G.1 Material Testing

Perform the following VT during placement:

- (1) Gradation,
- (2) Crushing,

- (3) Aggregate Quality and
- (4) Bitumen content (using procedure 1852 in the Laboratory Manual).
Sample the granular materials from the road core after spreading but before compaction.

Select crushing, aggregate quality and bitumen samples using the random sampling method in the Grading and Base manual. Select gradation samples from locations that are at risk of not meeting the specification requirements.

G.2 Compaction Testing

Test for Compaction using either:

- Penetration Index (PI) Method, or
- Specified Density Method, or
- Quality Compaction Method. (Verify by observation that each lift shows no further evidence of consolidation during compaction or under traffic).

Use the Specified Density method for acceptance for materials not meeting the requirements of 2105.1A7, "Granular Materials".

Use the granular penetration index method for materials meeting the requirements of 2105.1A7, "Granular Materials".

Test for compaction in areas with the greatest rutting or deflection, and near structures.

Correct any area represented by a failing test. Perform additional tests in areas with the greatest rutting or deflection.

Use the Specified Density Method for virgin materials only.

H Finishing Operations

Shape and maintain the roadway core to the required grade and cross section and within the tolerance in accordance with 2112.3.E, "Tolerances" until the next layer is placed.

Perform earthwork finishing and topsoil placement operations concurrently to allow timely completion of erosion control items. Shape and maintain disturbed areas outside the road core to final grade prior to placing erosion control. Scarify the surface to a minimum depth of 3 in [75 mm] before placing topsoil. Complete soil preparation, erosion control and turf establishment, as required by 2574, "Soil Preparation", and 2575, "Establishing Turf and Controlling Erosion".

I Disposition of Excavated Material

All surplus materials become the property of the Contractor. Dispose of these materials in accordance with a disposal plan approved by the Engineer. The disposal plan must comply with all applicable environmental regulations, permit requirements and 2104, "Removing Pavement and Miscellaneous Structures". Disposal of materials before acceptance of the disposal plan is unauthorized work in accordance with 1512, "Unacceptable and Unauthorized Work".

2105.4 METHOD OF MEASUREMENT

A Excavation Material

The Engineer will measure and calculate excavated material quantities according to 1901, "Measurement of Quantities".

The Engineer will investigate disputed quantities and may adjust quantities based on excavation and embankment measurements taken during construction and after completion, in accordance with 1901, "Measurement of Quantities".

Quantities are limited to measurements within specified construction limits and variances authorized by the Engineer.

The Engineer will measure excavated quantities by excavated volume (EV).

The Engineer will take measurements to determine the limits of material classifications during excavation.

A.1 Rock Excavation

The Engineer will include the following in the measurement for rock excavation:

- (1) Overbreakage if the plane of the bottom of the excavation falls within a layer or stratum of rock,
- (2) 6 in [150 mm] overbreak allowance outside the grading section or as indicated in the plans and
- (3) 24 in [600 mm] measured horizontally, overbreak allowance outside the backslopes for hard rock types.

The Engineer will not provide an allowance for overbreak of pre-split backslopes.

B Borrow Material

The Engineer will measure borrow material quantities by volume in accordance with 1901, "Measurement of Quantities."

The Engineer will deduct borrow quantities caused by excavation beyond the Contract limits.

The Engineer will deduct borrow quantities caused by placing embankment beyond the Contract limits.

The Engineer will measure all borrow quantities by compacted volume (CV).

C Salvage Material

The Engineer will measure salvage quantities by either loose volume (LV) or stockpile volume (SV).

D Stabilizing Aggregate

The Engineer will measure stabilizing aggregate quantities by compacted volume (CV).

2105.5 BASIS OF PAYMENT

A Stabilizing Aggregate

The contract cubic yard [cubic meter] price for *Stabilizing Aggregate* includes the cost of production, testing, compaction and placement.

B Salvage Materials

The contract unit price for salvage materials includes the cost of excavation, testing, delivery, and stockpiling at the site. The contract unit price for placing salvage materials from stockpiles includes all costs to use this material in the new construction.

C Borrow Materials

The contract unit price for borrow materials includes the cost of source preparation, excavation, testing, delivery, placement, compaction and final finishing.

Payment for necessary site preparation from required sources will be compensated separately or as 1402, "Contract Revisions".

The Department will pay the contract unit prices of both the excavation and borrow contract item for excess material used as a borrow item.

D Excavated Materials

The contract unit price for excavated materials includes the cost of excavation, testing, final placement, construction of steps in existing slopes and disposal.

If the plans do not include a contract pay item for removal and disposal of debris, the Department will pay for these in accordance with 1402, "Contract Revisions."

D.1 Channel and Pond Excavation

The Department will pay an additional \$1.00 per cubic yard [\$1.30 per cubic meter] when the Engineer reclassifies *Common Excavation* to *Channel and Pond Excavation*.

D.2 Rock Excavation

The Department will pay an additional \$20.00 per cubic yard [\$26.00 per cubic meter] when the Engineer reclassifies *Common Excavation*, *Subgrade*, or *Channel and Pond Excavation* to *Rock Excavation*. The Department can only apply this price adjustment if the contract does not contain *Rock Excavation* and cannot exceed 250 cu. yd. [200 cu. m].

D.3 Rock Channel Excavation

The Department will pay an additional \$100.00 per cubic yard [\$130.00 per cubic meter] when the Engineer reclassifies *Channel and Pond Excavation* to *Rock Channel Excavation*. The Department can only apply this price adjustment, if the contract does not contain *Rock Channel Excavation* and cannot exceed 25 cu. yd. [20 cu. m].

D.4 Muck Excavation

The Department will pay for muck excavation deeper than the depth shown on the plans, in accordance with Table 2105-7.

Table 2105-7	
Price Adjustments for Additional Muck Excavation	
Depth below natural surface	Compensation
0 ft. – 15 ft. [0 m – 5 m]	<i>Muck Excavation Contract Unit Price</i>
> 15 ft. – 20 ft. [> 5 m – 7 m]	<i>Muck Excavation Contract Unit Price plus \$0.30 per cubic yard [\$0.39 per cubic meter]</i>
> 20 ft – 25 ft. [> 7 m – 9 m]	<i>Muck Excavation Contract Unit Price plus \$0.50 per cubic yard [\$0.65 per cubic meter]</i>
> 25 ft. [> 9 m]	Negotiated Price
NOTE: These price adjustments are payment in full for all additional costs incurred. Exception: Compensation for additional Muck Excavation may be subject to the provisions of 1402, "Contract Revisions".	

E (Blank)

F (Blank)

G Partial Payment Withholdings

Comply with the payment withholding requirements of 2574, "Soil Preparation."

H Topsoil Borrow

The Department will pay for topsoil borrow in accordance with 2574, "Soil Preparation".

I Water

The cost of water used for compaction is incidental to embankment contract items.

J Monetary Price Adjustments Granular Materials

The Engineer may allow the Contractor to accept a monetary price adjustment instead of correcting failing granular material using granular monetary price adjustment tables found on the Grading and Base website.

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The Department will add monetary price adjustments for each failing aggregate quality, crushing, sieve and bitumen content test result.

The maximum monetary price adjustment is 50%. The Department will apply the monetary price adjustment against the entire quantity represented by the failing test.

K Contract Item Schedule

The Department will pay for excavation and embankment on the basis of the following schedule:

Item No.:	Item:	Unit:
2105.501	Common Excavation	cubic yard [cubic meter]
2105.503	Rock Excavation	cubic yard [cubic meter]
2105.505	Muck Excavation	cubic yard [cubic meter]
2105.507	Subgrade Excavation	cubic yard [cubic meter]
2105.511	Channel and Pond Excavation	cubic yard [cubic meter]
2105.513	Rock Channel Excavation	cubic yard [cubic meter]
2105.521	Granular Borrow (1)	cubic yard [cubic meter]
2105.522	Select Granular Borrow (1)	cubic yard [cubic meter]
2105.523	Common Borrow (1)	cubic yard [cubic meter]
2105.533	Salvage Aggregate (1)	cubic yard [cubic meter]
2105.535	Salvaged Topsoil (1)	cubic yard [cubic meter]
2105.541	Stabilizing Aggregate (1)	cubic yard [cubic meter]
2105.543	Stabilizing Aggregate	ton [metric ton]

NOTE: (1) Specify basis of measure: EV, LV, SV, or CV. See 2105.4 and 1901.

2111 TEST ROLLING

2111.1 DESCRIPTION

This work consists of providing and operating equipment to test roll roadway embankments.

A Definitions

A.1 Strip

Strip is the area covered by the rolling tire.

2111.2 EQUIPMENT

Provide a test roller meeting the following requirements:

A Pneumatic Tires

- (1) Two pneumatic tires spaced at least 6 ft [1.8 m] apart, center to center,
- (2) Tire sizes of 18 × 24 or 18 × 25, and
- (3) Inflate tires to 95 psi [650 kPa].

B Load

Provide a mass load on each tire from 14.9 ton to 15.1 ton [13.5 metric ton to 13.7 metric ton].

Position the roller tongue parallel to the grade at the time of testing.

C Deflection Measurement

Measure deflection from the top of the unrolled embankment to bottom of the rut at the time of rolling.

Mark failing areas with an approved deflection measurement device mounted over the center of the loaded axel and offset 12 inches [300 mm] from the outside edge of each tire. The Engineer may allow alternate deflection recording devices.

2111.3 CONSTRUCTION REQUIREMENTS

All forms and the Grading and Base Manual are available on the Grading and Base Website. Unless otherwise designated all test procedures are in the Grading and Base Manual.

Construct the embankment surface to the design cross section and profile as per 2112, "Subgrade Preparation."

After test rolling, repair and maintain the surface per 2112, "Subgrade Preparation" until placement of the next layer.

Test roll the entire length and width at the top of the subgrade (as defined in 2105), or as designated in the Contract, from shoulder point of intersection to shoulder point of intersection or curb line to curb line.

A Testing Requirements

Make two passes over each strip covered by the tire width for non-granular soils, and one pass over each strip covered by the tire for granular soils at an operating speed from 2.5 mph to 5 mph [4 kph to 8 kph]. Granular soils are defined in 2105.

Ensure that unrolled areas between each strip are no greater than 12 in [300 mm] wide.

Protect all structures from damage that may be caused by the test roller.

B Acceptance Requirements

Meet the applicable requirement.

- (1) Deflection no greater than 3 in [75 mm] for granular materials (do not place stabilizing aggregate prior to test rolling), or
- (2) Deflection no greater than 2 in [50 mm] for non-granular materials.

C Testing Corrected Areas

Repeat testing after all failing areas have been repaired.

The Engineer may waive repeat testing on corrected areas that are less than 2 road stations [50 m] in length.

2111.4 METHOD OF MEASUREMENT

The Engineer will measure test rolling by length for the entire width, when it is listed as a contract item in the contract.

The Engineer will separately measure test rolling on each roadbed for divided highways.

2111.5 BASIS OF PAYMENT

Test rolling on embankment constructed under this contract is incidental to the embankment contract item, unless it is listed as a separate contract item.

The Department will pay for all repairs to failing sections constructed under a previous contract in accordance with 1402, "Contract Revisions."

The Department will pay for test rolling embankment constructed under a previous contract based on the following schedule:

Item No.:	Item:	Unit:
2111.501	Test Rolling	road station [meter]

2112 SUBGRADE PREPARATION

2112.1 DESCRIPTION

This work consists of shaping, mixing, and compacting to the top of the subgrade, as defined in 2105, before placing the next layer.

2112.2 MATERIALS — (BLANK)

2112.3 CONSTRUCTION REQUIREMENTS

A General

All forms and the Grading and Base Manual are available on the Grading and Base Website. Unless otherwise designated all test procedures are in the Grading and Base Manual.

Scarify, mix, and compact the top 6 in [150 mm] of the subgrade. Correct areas represented by failing tests.

Excavation below the planned subgrade to correct unstable conditions may be subject to 1402, "Contract Revisions".

B Contractor QC Testing

Perform Contractor QC testing in accordance with the Schedule of Materials Control.

B.1 (Blank)

B.2 Moisture Control During Placement

Determine the moisture content during compaction using test methods approved by the Engineer.

Provide daily QC testing results for the moisture content to the Engineer.

Maintain the moisture content during compaction between 65 percent and 102 percent of optimum moisture content.

C Density

Achieve and maintain the density per the Specified Density Method in 2105, "Excavation and Embankment", until placement of the next Lift.

D Agency Verification Testing (VT)

Test according to the Schedule of Materials Control. The Engineer will test for compaction in areas with the greatest rutting or deflection. Retest failing areas after correction.

E Tolerances

Finish the surface of each layer within 0.05 ft [15 mm] above to 0.10 ft. [30 mm] below the cross section shown on the plans before placing the next layer.

2112.4 METHOD OF MEASUREMENT

The Engineer will measure subgrade preparation by length, along the centerline of the embankment. The Engineer will separately measure work on each embankment on divided highways.

2112.5 BASIS OF PAYMENT

The contract road station [meter] price for Subgrade Preparation includes all costs of subgrade preparation on embankment constructed as required by this contract.

Areas not represented by passing QC tests are unacceptable work per 1512, "Unacceptable and Unauthorized Work."

The Department will pay for subgrade preparation on the basis of the following schedule:

Item No.:	Item:	Unit:
2112.501	Subgrade Preparation	road station [meter]

2118 AGGREGATE SURFACING

2118.1 DESCRIPTION

This work consists of placing an aggregate wearing course on the roadway and shoulders.

2118.2 MATERIALS

A **Aggregate**..... **3138**

Provide the class of aggregate as required by the contract, except that class 1 with a minimum bitumen content of 1.5% may be substituted for class 2, when used for shoulder surfacing.

2118.3 CONSTRUCTION REQUIREMENTS

All forms and the Grading and Base Manual are available on the Grading and Base Website. Unless otherwise designated all test procedures are in the Grading and Base Manual.

Construct aggregate surfacing in accordance with 2211, "Aggregate Base." Use the Quality Compaction Method specified in 2211, "Aggregate Base". Maintain the moisture content at or above 5 percent by dry weight during compaction.

A Contractor Quality Control (QC) Testing

Comply with the QC requirements of 2211, "Aggregate Base", and the Schedule of Materials Control.

B Agency Verification Testing (VT)

Comply with the requirements of 2211.3.D, "Agency Verification Testing". Use 2211.3.D.2b, "Quality Compaction Method" to verify compaction. Test according to the Schedule of Materials Control.

2118.4 METHOD OF MEASUREMENT

The Engineer will measure the aggregate surfacing in accordance with 1901, "Measurement of Quantities."

The Engineer will not make deductions for the mass or volume of water and admixtures.

Mass and Volume conversion tables are in the Grading and Base Manual.

2118.5 BASIS OF PAYMENT

The contract unit price for the accepted quantities of material includes the costs of production, testing, placement and compaction.

All aggregate surfacing placed before the Engineer accepts the Contractor's certification is unauthorized work in accordance with 1512, "Unacceptable and Unauthorized Work."

The Engineer may allow the Contractor to accept a monetary price adjustment instead of correcting failing material in accordance with:

- Table 2211-4,
- Table 2211-5,
- Table 2211-6 and
- The monetary price adjustment table for aggregate surfacing quality on the Grading and Base

website.

The Department will add monetary price adjustments for each failing aggregate quality, crushing, sieve and bitumen content results.

The maximum monetary price adjustment is 50%.

The Department will apply the monetary price adjustment against the entire quantity represented by the failing test or lot.

The Department will pay for aggregate surfacing on the basis of the following schedule:

Item No.:	Item:	Unit:
2118.501	Aggregate Surfacing, Class ____	ton [metric ton]
2118.502	Aggregate Surfacing, (LV), Class ____	cubic yard [cubic meter]

2131 APPLICATION OF CALCIUM CHLORIDE

2131.1 DESCRIPTION

This work consists of applying calcium chloride as a surface treatment or as an admixture while grading or placing aggregate base or surface courses.

2131.2 MATERIALS

A Calcium Chloride3911

B Water

Provide water meeting the water quality rules established by the State of Minnesota.

2131.3 CONSTRUCTION REQUIREMENTS

All forms and the Grading and Base Manual are available on the Grading and Base Website. Unless otherwise designated all test procedures are in the Grading and Base Manual.

A Surface Application

Apply a uniform layer of dry or liquid calcium chloride following the rates listed in the Grading and Base Manual.

B Admixture Application

Use one of the following calcium chloride application methods:

- (1) Mix the calcium chloride with the aggregate during aggregate production. Use a separate conveyor or metering device to add calcium chloride to the aggregate.
- (2) Apply dry calcium chloride as a surface application and mix with the specified layer.
- (3) Apply calcium chloride solution as a surface application.

2131.4 METHOD OF MEASUREMENT

The Engineer will measure dry calcium chloride by weight and calcium chloride solutions by volume.

2131.5 BASIS OF PAYMENT

The Department will pay for the application of water used with dry calcium chloride in accordance with 2130, "Application of Water for Dust Control."

The Department will pay for the application of calcium chloride on the basis of the following schedule:

Item No.:	Item:	Unit:
2131.501	Calcium Chloride, Type ____	ton [metric ton]
2131.502	Calcium Chloride Solution	gallon [cubic meter]

BASE CONSTRUCTION

2211 AGGREGATE BASE

2211.1 DESCRIPTION

This work consists of placing aggregate base.

2211.2 MATERIALS

A Aggregate.....3138

Provide the class of aggregate as required by the contract.

2211.3 CONSTRUCTION REQUIREMENTS

All forms and the Grading and Base Manual are available on the Grading and Base Website. Unless otherwise designated all test procedures are in the Grading and Base Manual.

A General

Remove aggregate base, placed under the contract that saturates subgrade soils, and then dry and re-compact the subgrade.

Compact and shape the aggregate base, to the plan dimensions, before suspending operations.

B Contractor Quality Control (QC) Testing

Test according to the Schedule of Materials Control.

Certify materials on Form G&B-104 (Certification of Aggregate and Granular Materials). Attach all required aggregate test results to Form G&B-104.

Retest corrected base, which fails either QC or Verification Testing (VT). Correct failing material, before placing the next lift and provide copies to the Engineer before VT.

B.1 Aggregate Production

Perform the following QC tests during production:

- (1) Gradation,
- (2) Crushing,
- (3) Aggregate quality and
- (4) Bitumen content

B.2 Aggregate Placement

Perform the following QC tests during placement:

- (1) Gradation and
- (2) Moisture content during compaction using test methods approved by the Engineer.

Test for the moisture content in areas that appear least likely to meet specifications.

Provide the Engineer a copy of the test results on a daily basis.

C Placing and Compacting

Ensure the underlying layer meets QC and VT requirements before the next layer is placed.

Maintain the moisture content per Table 2211-1.

Table 2211-1 Moisture Required for Base Compaction	
Classification	Moisture Content (% by dry weight)
Class 3 and 4 ($< 2.5\%$ bitumen content)	$\geq 7\%$
Class 5, 5Q and 6 ($< 2.5\%$ bitumen content)	$\geq 5\%$
Classes 3, 4, 5, 5Q and 6 $\geq 2.5\%$ bitumen content	$3\% \geq$ moisture content $\leq 7\%$

Ensure the aggregate material has a uniform consistency before compaction.

Place and compact lifts per Table 2211-2.

Table 2211-2 Rollers Required for Compaction	
Base Lift Thickness / Bitumen Content	Required Rollers
≤ 3 in [75 mm] / Any Bitumen Content	Use Pneumatic Rollers only
> 3 in [75 mm] to ≤ 6 in [150 mm] / Bitumen Content $\leq 2.5\%$	Use both Vibratory and Pneumatic Rollers
> 3 in [75 mm] to ≤ 6 in [150 mm] / Bitumen Content $> 2.5\%$	Use both Vibratory Pad Foot roller weighing at least 25,000 lb. [11,300 kg] and 25 ton [22.7 tonne] Pneumatic Roller

Place and compact the base to support traffic, while allowing no greater than $\frac{1}{2}$ inch [13 mm] of surface displacement, when measured using a straightedge. Construct the aggregate layer to ± 0.05 ft [15 mm] of the profile and cross-section as required by the contract in accordance with 2112, "Subgrade Preparation." Maintain the compaction, quality, integrity, and properties of the aggregate material in each lift until the next lift or layer is placed.

Uniformly compact each lift to meet the VT criteria listed in the Contract. Use the 2211.3.D.2.c, "Penetration Index Method".

Correct, blend and re-compact aggregate material represented by failing tests.

D Agency Verification Testing (VT)

Test according to the Schedule of Materials Control.

D.1 Gradation and Aggregate Quality Sampling and Testing

Sample aggregates from the roadway after spreading but before compaction using the random sampling method in the Grading and Base Manual.

Test the entire lot or area of corrected material with new random samples. The Engineer will perform retests of gradation failures and provide results to the Contractor within 24 hours of receiving passing QC retests.

The Engineer will test materials for the contract item *Stockpile Aggregates* before delivery and stockpiling.

D.2 Compaction

The Engineer will test for compaction in the areas with the greatest rutting or deflection.

The Engineer will perform a new test in corrected areas with the greatest rutting or deflection.

The Engineer will test the compacted aggregate material using the Penetration Index Method per 2211.3.D.2.c, "Penetration Index Method", unless designated otherwise in the Contract. Other compaction testing methods include 2211.3.D.2.a, "Specified Density Method" and 2211.3.D.2.b, "Quality Compaction Method" and are listed below.

D.2.a Specified Density Method

Use the specified density method on virgin aggregates only.

Verify by testing that each lift is compacted to at least 100 percent of maximum density.

D.2.b Quality Compaction Method

Verify visually that each lift shows no further evidence of consolidation during compaction or under traffic.

D.2.c Penetration Index Method

Verify that each lift meets the penetration index and seating value per Table 2211-3.

Table 2211-3 Penetration Index Method — Maximum Seat and DPI				
Grading Number †	Moisture Content ‖	Maximum Allowable SEAT, [mm]	Maximum Allowable DPI, [mm/blow]	Test Layer, in [mm] *
3.1 – 3.5	< 5.0	40	10	4 – 6 [100–150]
	5.0 – 8.0	40	12	
	> 8.0	40	16	
3.6 – 4.0	< 5.0	40	10	4 – 6 [100–150]
	5.0 – 8.0	45	15	
	> 8.0	55	19	
4.1 – 4.5	< 5.0	50	13	5 – 6 [125–150]
	5.0 – 8.0	60	17	
	> 8.0	70	21	
4.6 – 5.0	< 5.0	65	15	6 – 12 [150–300]
	5.0 – 8.0	75	19	
	> 8.0	85	23	
5.1 – 5.5	< 5.0	85	17	7 – 12 [175–300]
	5.0 – 8.0	95	21	
	> 8.0	105	25	
5.6 – 6.0	< 5.0	100	19	8 – 12 [200–300]
	5.0 – 8.0	115	24	
	> 8.0	125	28	

† As determined by Form G&B-204
 ‖ Percent of dry weight.
 * If layer to be placed is thinner than the Test Layer, use 2211.3D.2b, "Quality Compaction Method".
 Note: When bitumen content is $\geq 2.5\%$, compact to achieve a penetration index value of 0.4 in [10 mm] and a seating value of 1.5 in [40 mm], as determined by Form G&B-205.

E Aggregate for the Contract Item Stockpile Aggregate

Produce and certify the class of material required by the contract using form G&B-104.

Deliver and stockpile certified material to the designated sites listed in the contract.

2211.4 METHOD OF MEASUREMENT

The Engineer will measure the aggregate base per 1901, "Measurement of Quantities". The Engineer will not deduct the mass or volume of water and admixtures.

Mass and Volume conversion tables are in the Grading and Base Manual.

2211.5 BASIS OF PAYMENT

The contract unit price for the accepted quantities of *Aggregate Base* includes the costs of production, testing, placement and compaction.

The contract unit price for the accepted quantities of *Stockpile Aggregate* includes the costs of production, testing, delivery and stockpiling at the designated site.

Aggregate base placed before the Engineer accepts the Contractor's certification is unauthorized work in accordance with 1512, "Unacceptable and Unauthorized Work."

The Engineer may allow the Contractor to accept a monetary price adjustment instead of correcting failing material in accordance with:

- Table 2211-4,
- Table 2211-5,
- Table 2211-6,
- The monetary price adjustment table for aggregate base quality on the Grading and Base website.

The Department will add monetary price adjustments for each failing aggregate quality, crushing, sieve and bitumen content results.

The maximum monetary price adjustment is 50%.

The Department will apply the monetary price adjustment against the entire quantity represented by the failing test or lot.

Table 2211-4 Aggregate Gradation Monetary Price Adjustment Schedule Based on the Average of 4 Samples per Lot			
Percent Passing Outside Specified Limits for Sieves			Monetary Price Adjustment %
2 in, 1½ in, 1 in, ¾ in, ½ in & No. 4 [50, 37.5, 25, 19, 9.5, 4.75 mm]	No. 10 & No. 40 [2.00 mm & 425 µm]	No. 200 [75 µm]	
3-5	1	0.1	5
—	—	0.2	6
6	—	—	7
7	—	0.3	9
8	—	0.4	11
9	—	—	13
—	—	0.5	14
10	2	0.6	15
> 10	> 2	> 0.6	Corrective action required

Table 2211-5 Aggregate Gradation Monetary Price Adjustment Schedule Based on an Individual or average of two or three Sample(s)			
Percent Passing Outside Specified Limits for Sieves			Monetary Price Adjustment %
2 in, 1½ in, 1 in, ¾ in, ⅜ in & No. 4 [50, 37.5, 25, 19, 9.5, 4.75 mm]	No. 10 & No. 40 [2.00 mm & 425 µm]	No. 200 [75 µm]	
3-5	1	0.1 – 0.6	1
—	—	0.7	2
6	—	0.8	3
—	—	0.9 – 1.0	4
7	—	1.1	5
—	—	1.2	6
8	—	1.3	7
—	—	1.4	8
9	—	1.5	9
—	2	1.6 – 1.7	10
10	—	1.8	11
—	—	1.9	12
—	—	2.0	13
—	—	2.1	14
—	3	2.2–2.5	15
>10	>3	>2.5	Corrective action required

Table 2211-6 Bitumen Content Monetary Price Adjustment Schedule	
Bitumen Content (Composite Mixture), %	Monetary Price Adjustment %
3.6	0% Substantial Compliance
3.7	1
3.8	2
3.9	3
4.0	4
4.1	6
4.2	8
4.3	10
4.4	12
4.5	15
> 4.5	Corrective action required

The Department will pay for aggregate base on the basis of the following schedule:

Item No.:	Item:	Unit:
2211.501	Aggregate Base, Class ____	ton [metric ton]
2211.502	Aggregate Base (LV), Class ____	cubic yard [cubic meter]
2211.503	Aggregate Base (CV), Class ____	cubic yard [cubic meter]
2211.505	Stockpile Aggregate, Class ____	ton [metric ton]
2211.506	Stockpile Aggregate (LV), Class ____	cubic yard [cubic meter]
2211.507	Stockpile Aggregate (SV), Class ____	cubic yard [cubic meter]

2212 DRAINABLE AGGREGATE BASE

2212.1 DESCRIPTION

This work consists of constructing a drainable Aggregate Base on a finished base or filter layer.

2212.2 MATERIALS

Provide the drainable base of the type designated in the Contact.

A..... Drainable Bases.....3136

2212.3 CONSTRUCTION REQUIREMENTS

All forms and the Grading and Base Manual are available on the Grading and Base Website. Unless otherwise designated all test procedures are in the Grading and Base Manual.

A General

Before placing the drainable base, shape the underlying surface in accordance with the contract and 2112.3.E, "Tolerances."

Maintain a uniform gradation during placement.

B Contractor Quality Control (QC) Testing

Test according to the Schedule of Materials Control.

Certify materials on Form G&B-104, "Certification of Aggregate and Granular Materials". Attach all required aggregate test results to Form G&B-104.

Retest corrected drainable aggregate base, which fails either QC or Verification Testing (VT).

B.1 Aggregate Production

Perform the following QC tests during production:

- (1) Gradation,
- (2) Crushing and
- (3) Aggregate quality.

B.2 Aggregate Placement

Perform QC gradation testing during placement.

Correct failing material before placing the next layer. Sample and test material after correction.

C Placing and Compacting

Maintain the moisture content from 3 to 7 percent by dry weight during compaction.

Provide placement equipment meeting the following requirements:

- (1) Will not rut the in-place surface,
- (2) Will not displace or damage the geotextile and
- (3) Capable of placing the required thickness without creating segregation.

Vibratory rollers are not allowed. Do not allow traffic on the drainable base after final placement and compaction. Use the quality compaction method per 2211.3.D.2.b, "Quality Compaction Method." Maintain drainage.

Construct the aggregate layer to ± 0.05 ft [15 mm] of the profile and cross-section as required by the contract in accordance with 2112, "Subgrade Preparation." Maintain the surface, quality, integrity, and properties of the aggregate material in each lift until the next lift or layer is placed.

D Agency Verification Testing (VT)

Test according to the Schedule of Materials Control.

Sample and test from the roadway after spreading but before compaction using the random sampling method in the Grading and Base Manual.

Test the entire lot or area of corrected material with new random samples. The Engineer will perform retests of gradation failures and provide results to the Contractor with 24 hours of receiving passing QC retests.

Verify compaction per 2211.3.D.2.b, "Quality Compaction Method."

2212.4 METHOD OF MEASUREMENT

Measure the material in accordance with 1901, "Measurement of Quantities".

2212.5 BASIS OF PAYMENT

The contract unit price for the accepted quantities of Drainable Aggregate Base includes the costs of production, testing, placement and compaction.

Drainable aggregate base placed before the Engineer accepts the Contractor's certification is unauthorized work in accordance with 1512, "Unacceptable and Unauthorized Work."

The Engineer may allow the Contractor to accept a monetary price adjustment, instead of correcting failing material in accordance with drainable aggregate gradation and quality monetary price adjustment tables on the Grading and Base website.

The Department will add price adjustments for each failing sieve and quality content result.

The maximum monetary price adjustment is 50%.

The Department will apply the price adjustment against the entire quantity represented by the failing test or lot.

The Department will pay for drainable base on the basis of the following schedule:

Item No.:	Item:	Unit:
2212.501	Drainable Aggregate Base, Type (1) (CV)	cubic yard [cubic meter]
	Note (1): Specify Type either OGAB or DSB.	

2215 FULL DEPTH RECLAMATION (FDR)

2215.1 DESCRIPTION

This work consists of pulverizing and blending the in-place bituminous pavement with a portion of the underlying material to produce a uniformly mixed aggregate base.

This work will include spreading, watering, compacting, shaping and maintaining the blended reclaim material to the specified profile and cross-section.

2215.2 MATERIALS

A..... Modified Aggregate Bases.....3135

2215.3 CONSTRUCTION REQUIREMENTS

All forms and the Grading and Base Manual are available on the Grading and Base Website. Unless otherwise designated all test procedures are in the Grading and Base Manual.

A General

Remove all reclaimed pavement pieces that would be retained on the three inch sieve, from the right-of-way.

Repair structures damaged by Contractor operations.

Bituminous FDR may only be used within or above the road core as defined in 2105, "Excavation and Embankment".

B Equipment Requirements

B.1 Reclaiming Machine

Use a road reclaiming machine capable of uniformly pulverizing the pavement and the underlying layer to the specified depth and gradation.

B.2 Rollers

B.2.a Pneumatic-Tired Roller

Use a pneumatic-tired roller weighing at least 25 ton [22.7 tonne] or 616 lb per in [111 kg per cm] of rolling width. Ensure the tire arrangement allows compaction over the full width of the roller with each pass.

B.2.b Pad Foot Vibratory Roller

When required in 2215.3E, use a pad foot roller weighing at least 25,000 lb [11,300 kg].

C Contractor Quality Control (QC) Testing

Test according to the Schedule of Materials Control.

Submit results to the Engineer within 24 hours of the completion of the tests.

Measure the reclaim depth.

Sample and test for gradation within the first 500 ft [150 m] of production and within 500 ft [150 m] after a failing gradation.

Chart all data on a Quality Control Chart per Grading and Base Manual Section 5-692.111. Chart all data daily and provide to the Engineer when requested.

Correct and retest all failing areas, which fail either Quality Control or Verification Testing.

D Pulverizing Operation

Before beginning pulverization, remove vegetation and topsoil adjacent to the surface.

Blend, add water, spread, compact, and shape pulverized material by the end of the workday.

Uniformly spread additional aggregate material across the roadway surface before blending it into the reclaim mixture.

Protect and avoid damaging existing structures during pulverization.

Correct reclaim sections represented by a failing gradation.

E Placing and Compacting

Uniformly mix reclamation material before spreading.

Spread and compact the reclamation material to the profile and cross section shown on the plans before placing the next layer.

Maintain the moisture content from 3 to 7 percent by dry weight during compaction.

Place and compact reclamation materials in maximum 3-inch [75 mm] lifts using a pneumatic-tired roller in compliance with 2215.3.B.2a.

For lifts thicknesses from 3 inches [75 mm] to 6 inches [150 mm] compact using both a pneumatic-tired and pad foot vibratory rollers in compliance with 2215.3.B.2.

The Engineer may allow the contractor to compact using a lift thickness up to 12 inches [300 mm], as long as good compaction results are obtained.

The Contractor may use excess reclamation material from other locations on the project to attain the profile or cross-section as shown on the plans.

Compact to achieve a penetration index value of 0.4 in [10 mm] and a seating value of 1.5 in [40 mm] as measured by the MnDOT Standard Dynamic Cone Penetrometer (DCP) method, as determined by Form G&B-205.

Place and compact to support traffic, while allowing no greater than ½ inch [13 mm] of surface displacement, when measured using a straightedge. Construct the layer to ±0.05 ft [15 mm] of the profile and cross-section as required by the contract in accordance with 2112, "Subgrade Preparation." Maintain the compaction, quality, integrity, and properties of the aggregate material in each lift until the next lift or layer is placed.

F Agency Verification Testing (VT)

Test according to the Schedule of Materials Control.

Test compaction using the Penetration Index Method.

Sample for gradation, according to the Grading and Base Manual, after spreading but before compaction. Measure the reclaim depth.

The Engineer will sample and test the reclaim material after receiving acceptable test results from the Contractor.

G Workmanship, Quality, Repair and Maintenance

The Engineer will provide staking to re-establish the centerline, when Contractor-staking is not required by the contract.

Repair ruts, potholes, wash-boarding and other distortions by scarifying to a depth of 2 inches [50 mm] below the deepest distortion and re-compact.

2215.4 METHOD OF MEASUREMENT

The Engineer will measure the reclamation area by the length and width.

2215.5 BASIS OF PAYMENT

The contract unit prices for the reclamation material contract items includes the cost of production, testing, placement, occasional variations in the bituminous pavement thickness, removing vegetation and topsoil adjacent to the surface, repair to structures damaged by Contractor's operations and necessary maintenance.

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

Item No.:	Item:	Unit:
2215.501	Full Depth Reclamation	square yard [square meter]
2215.502	Haul Full Depth Reclamation (LV)	cubic yard [cubic meter]

2221 SHOULDER BASE AGGREGATE

2221.1 DESCRIPTION

This work consists of placing Contractor-certified aggregate on shoulder base adjacent to pavements.

2221.2 MATERIALS

A **Aggregate**..... **3138**

Use the class of aggregate required by the contract.

2221.3 CONSTRUCTION REQUIREMENTS

A General

All forms and the Grading and Base Manual are available on the Grading and Base Website. Unless otherwise designated all test procedures are in the Grading and Base Manual.

Comply with the requirements of 2211.3.A, "Construction Requirements, General."

B Contractor Quality Control (QC) Testing

Comply with the requirements of 2211.3.B, "Contractor Quality Control (QC) Testing."

C Shoulder Preparation

Comply with the requirements of 2211.3.C, "Placing and Compacting"; however, compact the existing material using the Quality Compaction Method as specified in 2211.3.D.2.b, "Quality Compaction Method."

Remove vegetation and replace contaminated material as directed by the Engineer.

Shape the bottom of the proposed shoulder aggregate to the grade and cross section as shown on the plans.

Do not place shoulder aggregate on the existing pavement surface.

Immediately sweep spilled material from the pavement surface.

D Agency Verification Testing (VT)

Comply with the requirements of 2211.3.D, "Agency Verification Testing". Test according to the Schedule of Materials Control.

E Tolerances

Construct aggregate shouldering in accordance with 2112.3.E, "Tolerances."

2221.4 METHOD OF MEASUREMENT

The Engineer will measure the shoulder aggregate in accordance with 1901, "Measurement of Quantities."

The Engineer will not deduct the mass or volume of water and admixtures.

Mass and Volume conversion tables are in the Grading and Base Manual.

2221.5 BASIS OF PAYMENT

The contract unit price for placing shoulder base aggregate includes the costs of the removing vegetation, production, testing, placement, compaction and shaping.

All shoulder base aggregate placed before the Engineer accepts the Contractor's certification is unauthorized work in accordance with 1512, "Unacceptable and Unauthorized Work."

The Engineer may allow the Contractor to accept a monetary price adjustment instead of correcting failing material in accordance with:

- Table 2211-4,
- Table 2211-5,
- Table 2211-6 and
- The monetary price adjustment table for shoulder base aggregate quality on the Grading and Base website.

The Department will add monetary price adjustments for each failing aggregate quality, crushing, sieve and bitumen content results.

The Department will apply the monetary price adjustment against the entire quantity represented by the failing test or lot.

The maximum monetary price adjustment is 50%. The Department will pay for shoulder base aggregate on the basis of the following schedule:

Item No.:	Item:	Unit:
2221.501	Shoulder Base Aggregate, Class ____	ton [metric ton]
2221.502	Shoulder Base Aggregate (LV), Class ____	cubic yard [cubic meter]
2221.503	Shoulder Base Aggregate (CV), Class ____	cubic yard [cubic meter]

2231 BITUMINOUS SURFACE RECONDITIONING

2231.1 DESCRIPTION

This work consists of reconditioning the existing pavement surface before constructing a bituminous overlay or surfacing courses.

2231.2 MATERIALS

A.....Bituminous Patching Mixture

Provide bituminous patching material matching the type of material used in the first layer of bituminous surfacing placed on the reconditioned surface.

B.....Mixture for Joints and Cracks

Provide a mixture for joints and cracks consisting of a prepared mix of fine aggregate and bituminous material in accordance with the following requirements:

Table 2231-1 Joint and Cracks Mixture Requirements	
Material	Requirement, %
Aggregate gradation*:	
½ in [12.5 mm] sieve	100
No. 8 [2.00 mm] sieve	45 – 80
No. 200 [75 µm] sieve	2.0 – 7.0
Aggregate spall	< 5
Bituminous material	6.5 – 7.0†
* Percent passing requirement.	
Match PG grade to grade used on first lift of plant mixed asphalt.	
† Percent by weight.	

C.....Joint and Crack Filler

Provide joint and crack filler in accordance with the special provisions.

2231.3 CONSTRUCTION

A.....Surface Repair

Remove loose, unstable, or deteriorated portions of the existing pavement to provide a stable surface after completion of the patching operation. Remove waste or surplus material from the project. Repair and fill the holes and depressions with mix in accordance with the special provisions. Compact the mix using conventional pneumatic tire roller or mechanical tampers in areas inaccessible to conventional roller equipment.

B.....Joint Repair

B.1.....Concrete Pavement

Clean and refill joints and cracks at least ¼ in [6 mm] wide.

B.2.....Bituminous Pavement

Rout and seal cracks ¼ in to ¾ in [6 mm to 20 mm] wide. For cracks greater than ¾ in [20 mm] wide, fill with the mixture for joints and cracks and tamp in place.

2231.4 METHOD OF MEASUREMENT

The Engineer will separately measure the accepted quantities of bituminous patching mixture, mixture for joints and cracks, and joint and crack filler, as provided and placed, by the weight or by the loose volume of material as shown on the plans.

2231.5 BASIS OF PAYMENT

The contract unit prices for *Bituminous Patching Mixture*, for *Mixture for Joints and Cracks*, and for *Joints and Crack Filler* include the cost of removing and disposing of the existing deteriorated materials.

If the contract does not specify a specific contract pay item for removing concrete base or pavement in accordance with 2104, "Removing Pavement and Miscellaneous Structures," the Department will pay for the removal of a concrete base or pavement to full depth and width between existing joints, or by sawing, as extra work in accordance with 1402, "Contract Revisions."

The Department will pay for bituminous surface reconditioning on the basis of the following schedule:

Item No.:	Item:	Unit:
2231.501	Bituminous Patching Mixture	ton [metric ton]
2231.502	Bituminous Patching Mixture	cubic yard [cubic meter]
2231.505	Mixture for Joints and Cracks	pound [kilogram]
2231.507	Joint and Crack Filler	pound [kilogram]

2232 MILL PAVEMENT SURFACE

2232.1 DESCRIPTION

This work consists of removing the existing pavement by cold milling.

2232.2 MATERIALS — (BLANK)

2232.3 CONSTRUCTION REQUIREMENTS

A..... Equipment

Mill the existing pavement with a power operated, self-propelled cold milling machine capable of removing concrete and bituminous materials to the profile, cross-slope, grade, and elevation uniformly across the pavement surface as shown on the plans. Use automatic controls to control grade, elevation, cross-slope, and profile. Use a machine with ski, matching shoe, or an independent grade control to reference the existing pavement and automatically establish profile grades along each edge of the machine within $\pm\frac{1}{4}$ in [6 mm].

B..... Operations

Mill the pavement surface to the depth, width, grade, and cross-slope as shown on the plans. Perform milling without tearing or gouging the underlying material. Surface irregularities exceeding $\frac{1}{2}$ in [6 mm] under a 10-foot [3-meter] straightedge laid transversely and longitudinally after milling is complete are unacceptable. Reference the milling operation from an independent grade control in areas directed by the Engineer. Establish and maintain grade control as approved by the Engineer.

Mill the entire pavement width to a flush surface at the end of each work period, when the pavement is open to traffic. If uncompleted operations result in a vertical or near vertical longitudinal face, re-slope the longitudinal face to provide a taper, construct a temporary bituminous taper or provide protective measures, as approved by the Engineer. Taper transverse cutting faces at the end of each working period where pavement is open to traffic. Construct temporary bituminous tapers at intersecting streets, around utility appurtenances, and appropriated entrances during the milling operations, as directed by the Engineer.

Mill areas inaccessible to the milling machine using other equipment or methods as approved by the Engineer.

The Contractor may recycle the surfacing removed by the milling operations and use on the project in accordance with 3138, "Aggregate for Base and Surface Courses," or 3139, "Graded Aggregate for Bituminous Mixtures," or dispose of the millings outside the right-of-way in accordance with 2104.3, "Removing Pavement and Miscellaneous Structures, Construction Requirements."

After milling to the depth shown on the plans, sweep or vacuum clean the milled area with equipment approved by the Engineer. Clean the milled area as approved by the Engineer. Dispose of debris from milling and cleaning operations outside of the right-of-way in accordance with 2104.3, "Removing Pavement and Miscellaneous Structures, Construction Requirements," except as otherwise approved by the Engineer.

Mill previously patched areas to the specified depth below the pavement surface that existed before placement of the previous patch, and not from the surface of the patch.

Avoid disturbing or damaging existing drainage or utility structures on the project. Repair damage resulting from the milling operations at no additional cost to the Department.

Keep the milled pavement surface free of all loose materials and dust.

2232.4 METHOD OF MEASUREMENT

The Engineer will measure pavement milling by the area of each type of surface removed. The Engineer will measure areas milled, based on actual finished dimensions of the work.

2232.5 BASIS OF PAYMENT

The contract unit price for pavement milling includes the cost of traffic safety, cleanup, and disposal operations.

The cost of constructing a temporary milled taper and providing, placing, and removing temporary bituminous tapers is included in the contract unit price for other relevant contract items.

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

Item No.:	Item:	Unit:
2232.501	Mill Bituminous Surface ___ in [___mm]	square yard [square meter]
2232.502	Mill Concrete Surface ___ in [___mm]	square yard [square meter]

PAVEMENT CONSTRUCTION

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 ₂ O ₃ + Al ₂ O 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 ($\text{Na}_2\text{O} + 0.658 \text{K}_2\text{O}$)
- (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.
- (7) Maximum of 33 percent substitution of Class C or Class F Fly Ash for concrete pavement, on a one for one basis, by weight of the designed portland cement;
- (8) Maximum of 35 percent substitution of slag, on a one for one basis, by weight of the designed portland cement; and
- (9) Ternary mixes (portland cement and two other supplementary cementitious materials) are allowed when approved by the Engineer, in conjunction with the Concrete Engineer, or required by or allowed in the contract.

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 $\text{SiO}_2 + \text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$ on a dry weight basis for at least 12 consecutive months and at least 38 percent SiO_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 \pm 0.10 cu. ft [1.000 cu. m \pm 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 \pm 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 0.42;
- (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 to the primary concrete plant only.

D.3 Job Mix Formula

Use at least two fractions of coarse aggregate that include the $\frac{3}{4}$ in+ [19 mm+] and $\frac{3}{4}$ 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.

Take samples at the belt leading to the weigh hopper or other locations close to the incorporation of the work as approved by the Engineer. 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. Test and record the individual results.

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 four 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 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 as determined by the Engineer. 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 subplot by a random number to obtain the position in the subplot 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:

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

X_i = individual test results

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

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

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.

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%	≤8%
No. 200 [75 µm]	≤8%	≤8%

- (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: $CF = \frac{\text{Combined \% retained above } 3/8 \text{ in [9.5 mm] sieve}}{\text{Combined \% retained above No.8[2.36 mm] sieve}} \times 100$	
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 subplot values on each sieve for the gradation band or the cumulative average of the subplot 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]

E	Reinforcement Bars	3301
F	Dowel Bars	3302
G	Concrete Joint Sealers	
G.1	Preformed Type.....	3721
G.2	Hot-poured, Elastic Type	3725
G.3	Silicone Type.....	3722
H	Preformed Joint Filler	3702
I	Curing Materials	
I.1	Burlap Curing Blankets.....	3751
I.2	Poly-Alpha Methylstyrene (AMS) Membrane Curing Compound	3754
I.3	Linseed Oil Membrane Curing Compound	3755
I.4	Plastic Curing Blankets	3756
J	Form Coating Material.....	3902

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

Provide notice 16 hrs in advance of concrete paving 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 $\geq 3,500$ cu. yd [2,900 cu. m]," provide a separate combination plant lab – office in accordance with 1604, "Plant Inspection – Commercial Facility," 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) Heating and cooling system capable of maintaining a uniform temperature between 72° and 85° F [22° and 29° C],
- (7) Drinking water container or cooler with adequate supply of potable water,
- (8) Detached portable toilet conveniently located,
- (9) Electrical power supply that provides adequate amperage for all electrical needs,
- (10) Water supply (storage tank with a capacity of 50 gal or more, or pressurized water supply) connected to the sink faucet,
- (11) Provide a sample storage area to prevent contamination of the samples,
- (12) Plant lab furnished in accordance with the following:
 - (12.1) One sturdily-built workbench or countertop at least 30 in \times 144 in [0.75 m \times 3.65 m],
 - (12.2) One service sink located near one end of the workbench with a water supply, faucet and an outside drain,
 - (12.3) Shelf space above workbench or countertop or at other convenient locations, totaling at least 8 linear ft [2.5 m] \times 8 in [0.2 m],
 - (12.4) Electronic scales of sufficient size to weigh the samples for all required materials testing, and
 - (12.5) A four (4) burner 30" standard electric stove top or stove and at least two (2) additional electric burners to perform required aggregate testing per the Schedule of Materials Control.
 - (12.6) Microwave oven with turntable or wave deflection fan (900 Watt), heat resistant glass pan (approx. 9"x9"x2"), plain weave fiberglass cloth (10 oz/yd² and 14 mills thick), metal scrapper and grinding pestle,
 - (12.7) Metal bowls of sufficient size to perform all required material testing,
- (13) Plant office furnished in accordance with 2031.3.B.1, "Field Office Furnishings," except as modified by the following:

- (13.1) Two desks, one for the Department and one for the Contractor, with total exterior dimensions of at least 30 in × 60 in [$\frac{3}{4}$ m × 1.50 m],
- (13.2) At least six desk chairs,
- (13.3) A telephone capable of providing email, and
- (13.4) A printer with scanning and copying capabilities.

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

For concrete paving projects supplied by a Certified Ready-Mix Plant, the separate Combination Plant - Lab Office requirements in 2301.2.A.3 a do not apply, with the exception of the following:

- (1) Electrical power supply that provides adequate amperage for all electrical needs,
- (2) Water supply (storage tank with a capacity of 50 gal or more, or pressurized water supply) connected to the sink faucet,
- (3) Electronic scales of sufficient size to weigh the samples for all required materials testing,
- (4) At least six (6) electric burners to perform required aggregate testing per the Schedule of Materials Control.
- (5) Metal bowls of sufficient size to perform all required material testing, and
- (6) If w/c incentives apply, provide a microwave oven with turntable or wave deflection fan (900 Watt), heat resistant glass pan (approx. 9"x9"x2"), plain weave fiberglass cloth (10 oz/yd² and 14 mills thick), metal scrapper and grinding pestle.

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 subplot,
- (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 2105, "Excavation and Embankment," 2112, "Subgrade Preparation," and 2211, "Aggregate Base," and the following:

Fine grade the aggregate base 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 $\frac{1}{8}$ in [3 mm] in any 10 ft [3 m] section,
- (5) Faces of straight forms with deviations no greater than $\frac{1}{4}$ 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 an approved 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 dense and homogenous 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 progress 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 both the elevation and longitudinal line 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.

When constructing concrete overlays, set and use string lines for grade control on both sides of the roadway during paving operations.

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 Concrete Ingredient Summaries

If delivering bulk cementitious materials directly to the concrete batching plant in railroad cars or sealed transport trucks, submit copies of the bill of ladings to the Engineer on the same day received from the transporting company.

Advise the Engineer of the method and schedule of cementitious material unloading. Do not unload cementitious materials until the Engineer approves the operation.

Each day of concrete pavement production, provide the Engineer with a production summary in an electronic format that includes the following:

- (1) Daily total concrete produced in cubic yards for each concrete mixture type.
- (2) Daily total ingredient quantities (aggregate, cementitious and water) including the percent overrun/underrun.

The Contractor shall provide final project total quantities for (1) and (2) to the Engineer at the end of the Project.

The Engineer will verify the following:

- (1) Individual daily cement quantity do not show an underrun in cement usage greater than 1.0 percent of the quantity specified,
- (2) The final cement quantity summary 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

Do not dump concrete directly onto the grade unless approved by the Engineer. Dump or discharge concrete without causing grade displacement or damage to the existing asphalt or bond breaker layer. Repair damage to the grade in accordance with 2301.3.B, "Subgrade and Aggregate Base Preparations," existing asphalt or bond breaker layer as approved by the Engineer at no additional cost to the Department. 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 breakers, 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 $\frac{3}{16}$ 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 $\frac{1}{2}$ 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 $\frac{1}{8}$ 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 \pm 1.5 percent of the measured volume of the plastic concrete before consolidation 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 LIT 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 $\frac{3}{8}$ 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."

I.1 Pavement Texture

Pull a carpet drag or broom 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.

When using a carpet drag method, 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 $\frac{5}{8}$ 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].

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.

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 $\frac{1}{25}$ 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 subplot as the rate at which an individual measurement is taken over a given length. The Department considers a subplot 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 provide the Contractor with the locations using a random number multiplied by length of the subplot within 24 hours of pavement placement. 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 48 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. If the Engineer determines by visual inspection, that areas not represented by random testing appear to not meet the minimum requirements of Table 2301-13, the Engineer reserves the right to require additional testing in those specific areas to determine compliance.

Table 2301-13 Pavement Texture Depth	
Texture Depth Test Results for Individual Tests	Acceptance Criteria
$< \frac{1}{25}$ in to $\geq \frac{1}{32}$ 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 $\frac{1}{25}$ 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.
$< \frac{1}{32}$ in [< 0.80 mm]	Perform concrete grinding of the pavement represented by this test to attain the necessary texture of $\frac{1}{25}$ 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.

J Concrete Curing and Protection

After completing final finishing operations, cure all exposed concrete surfaces. Use one 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 m²) 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 sy
- (2) stem 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 36 °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.1.a, "Membrane Curing Method."

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 subplot as the rate at which an individual measurement is taken over a given length. The Department considers a subplot 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 subplot.

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 subplot;
- (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 subplot. 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 $\frac{1}{8}$ 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 $\frac{1}{8}$ in [even mm].

N.4 Quality Acceptance Testing – Coring

The Engineer will measure the pavement thickness of concrete for each subplot 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 subplot for a PVC. The Engineer will mark one QAC per subplot.

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 $\frac{1}{8}$ 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 $\frac{1}{2}$ in [13 mm]. If the QCP measurement shows a thickness deficiency greater than PTL minus $\frac{1}{2}$ 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 $\frac{1}{2}$ 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 $\frac{1}{2}$ 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 $\frac{1}{2}$ in [13 mm], the Engineer will not require additional cores from this location. If any cores do not fall within the PTL minus $\frac{1}{2}$ 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 $\frac{1}{2}$ 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 $\frac{1}{2}$ 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 [≤ 3.0]	None (tolerance)
0.11 – ≤ 0.20 [3.1 – ≤ 5.0]	\$0.20 [\$0.25]
0.21 – ≤ 0.30 [5.1 – ≤ 8.0]	\$0.40 [\$0.50]
0.31 – ≤ 0.40 [8.1 – ≤ 10.0]	\$0.70 [\$0.90]
0.41 – ≤ 0.50 [10.1 – ≤ 13.0]	\$1.00 [\$1.25]
0.51 – ≤ 1.00 [13.1 – ≤ 25.0]*	\$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 for 7 days, or until the concrete 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 occurs first.

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) 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
- (3) 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 concrete pavement placed by area based on specified dimensions, including integrant curb. This measurement will represent the surface area of the pavement as constructed.

B.1 Structural Concrete

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

- (1) Measure the volume of structural concrete placed to a variable cross-section thickness using the average end-area method.
- (2) Verify the volume measurements from the computerized batch ticket printouts from the plant, as verified by 2301.3.E.2, "*Concrete Ingredient Summaries*," and the consideration of any waste as agreed with the Engineer.
- (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 based on the cubic yard [cubic meter] of *Structural Concrete*.

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, the Engineer will consider the contract square yard [square meter] price for *Concrete Pavement* to include 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; protecting; sawing; and sealing 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; protecting; sawing; and sealing 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, the Engineer will consider the contract square yard [square meter] price for *Place Concrete Pavement* to include 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 final volume of *Structural Concrete*, *Structural Concrete High Early*, or both for the entire project. 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 final volume valid, the Engineer will pay for the additional volume up to 102 percent of the calculated quantity for the entire project. 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]

2353 ULTRATHIN BONDED WEARING COURSE (UTBWC)

2353.1 DESCRIPTION

This work is the construction of an ultrathin bonded wearing course on a prepared pavement. An ultrathin bonded wearing course is the application of a polymer modified emulsion membrane followed immediately with an ultrathin wearing course mixture.

2353.2 MATERIAL REQUIREMENTS

A. Bituminous Materials

A.1 Polymer Modified Emulsion Membrane

Provide a polymer modified emulsion membrane meeting the requirements of 3151.2.G

A.2 Asphalt Binder

Use a Performance Graded binder, PG 64-34 that meets Mn/DOT 3151.2.A.

B. Aggregate

Meets MnDOT 3139.4.

B.3 Mineral Filler

Mineral filler shall meet the requirements in AASHTO M 17.

C. Mix Design.

It is the Contractor's responsibility to design the UTBWC mixture that meets the requirements of this specification.

At the optimum binder content the mixture must meet the requirements in Table 2353- 1, "UTBWC Mixture Requirements".

Each design shall include the additional design trial points that bracket the optimum AC content and with at least one point at 0.4 above and below the optimum AC content. Draindown testing and adjusted AFT determinations are required on these trial points.

D. Mix Design Submittal

Submit a proposed job mix formula (JMF) in writing to the Department Bituminous Engineer for review as specified meeting the requirements in Table 3139-9, "UTBWC Aggregate Gradation Broadband" and Table 2353-1, "UTBWC Mixture Requirements" and include the following:

- (1) Source, pit ID and description of the materials used.
- (2) The proportion and gradation of each material in the JMF.
- (3) The composite gradation of the design blend.
- (4) 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 Mn/DOT Laboratory Manual Method 1204 and 1205. The tolerance allowed between the Contractor's and the Department's specific gravities are Gsb (individual) = 0.040 [+4 and -4] and Gsb (combined) = 0.020.
- (5) Test results and worksheets for all properties required in Tables 2353-1, "UTBWC Mixture Requirements" and Tables 3139-7 to 9.
- (6) Testing results and worksheets for the additional design points that bracket the optimum AC point.

Table 2353-1 UTBWC Mixture Requirements		
Test	Criteria	Test Reference
Asphalt Content	4.8-6.0	Mn/DOT Laboratory Manual 1853 or 1852
Adj. AFT (Calculated)	10.5 µm minimum	Mn/DOT Laboratory Manual 1854
Draindown Test	0.10% max	AASHTO T 305
Lottman (TSR)	80% min, 7-8% Voids	Mn/DOT Laboratory Manual 1813

D.1 Job Mix Formula Properties

Base gradation, asphalt binder content and adjusted AFT on the current Department reviewed Mixture Design Report. The JMF limits are the target plus or minus the limits in accordance with table 2353-2, "UTBWC JMF Limits." Use JMF limits as the criteria for acceptance of materials based on individual sample testing. Stop production if the test results vary from the JMF by more than the limits in Table 2353-2, "UTBWC JMF Limits". Identify the cause and document, in detail the corrective action. The JMF may only be adjusted if the revised JMF meets the mixture requirements in Tables 2353-1, "UTBWC Mixture Requirements" and Table 3139-9, "UTBWC Aggregate Gradation Broadbands". Do not resume paving until brought back into specification limits.

Table 2353-2 UTBWC JMF Limits	
Gradation	Broad Band Limits
Asphalt Content	±0.4*
Adj. AFT	-0.5*
*Note: The above limits shall not exceed the "Mixture Requirements" in Table 2353-1	

D.1 JMF Adjustments

The Contractor may make a request to the Bituminous or District Materials Engineer for a JMF adjustment if the QC test results indicate a necessary change to the design. A Certified Level II Bituminous QM Mix Designer will review the requested change for the Department. If the request meets the requirements in Table 3139-9, "UTBWC Aggregate Gradation Broadband" and Table 2353-1, "UTBWC Mixture Requirements", a revised Mixture Design Report will be issued.

2353.03 CONSTRUCTION REQUIREMENTS

A. Weather restrictions

The pavement surface temperature and ambient air temperature shall be at least 50 °F [10 °C]. A damp pavement surface is acceptable, if it is free of standing water and favorable weather conditions are expected.

B. Surface Preparation

Complete the following incidental work prior to the paving operations. Remove thermoplastic and tape traffic markings greater than 0.2-in [5-mm] thick. Protect manhole covers, drain, grates catch basins, and other utility structures with plastic or building felt. Clean the pavement surface.

C. Equipment

Use a paver, designed and built for the purpose of applying the ultrathin bonded wearing course. The paving machine shall incorporate a receiving hopper, feed conveyor, a storage tank for polymer modified emulsion membrane, polymer modified emulsion membrane spray bar and a variable width, heated, tamper bar screed. The screed shall have the ability to crown the pavement at the center both positively and negatively and have vertically adjustable extensions to accommodate the desired pavement profile.

D. Paving

Mixture must be produced by a certified plant.

Apply the polymer modified emulsion membrane and the ultrathin bonded wearing course in one pass. Spray the polymer modified emulsion membrane so it is not driven on, immediately prior to the application of the UTBWC. Use a metered mechanical pressure spray bar at a temperature of 120 – 180 °F [50 – 80 °C]. Accurately and continuously monitor the rate of spray and provide a uniform application across the entire pavement width. Use a spray rate in the range of 0.20 gal/yd² + 0.07 gal/yd² [0.85 l/m² + 0.3 l/m²]. Make adjustments based upon the existing pavement surface conditions and recommendations of the polymer modified emulsion membrane supplier. Apply the UTBWC at a temperature of 290 – 330 °F [143 – 165 °C] as measured in front of the screed. No wheel or other part of the paving machine shall come in contact with the polymer modified emulsion membrane before the UTBWC is applied. Use a heated, combination vibratory-tamping bar screed. Open the new pavement to traffic after the rolling operation is complete and the material has cooled below 158 °F [70 °C].

E. Thickness

The minimum finished wearing course thickness is 5/8-in [16-mm] with a maximum 1/2 inch [12.5 mm] vertical edge at the adjacent shoulder pavement edge.

F. Rolling

Roll the wearing course a minimum of two passes, before the material temperature has fallen below 185 °F [85 °C].

Use steel double drum asphalt rollers with a minimum weight of 11 tons [10 tonnes]. Do not allow the roller(s) to remain stationary on the freshly placed UTBWC. Roll in static mode only immediately following the placement of the UTBWC in order to seat the mix.

G. Pavement Smoothness

Conduct paving operations to produce a smooth UTBWC. The UTBWC surface will show no variation greater than 1/8 inch [3 mm] from the edge of a 10 foot [3 m] straightedge laid parallel to or at right angles to the centerline.

Pavement Surface Smoothness 2399 is required to be followed except for the following changes.

Replace section 3.C.2 with the following:

For UltraThin Bonded Wearing Course projects, ALR will be collected only on asphalt pavement laid during this project before the UTBWC. No smoothness will be paid for on the asphalt pavement. 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.

Replace the first paragraph in section 3.D.1 with the following:

Evaluate smoothness requirements after the UTBWC is laid using equations and criteria in accordance with the following tables:

- (1) Table 2399 4 for bituminous pavements,
- (2) Table 2399 6 for percent improvement projects.

No ALR will be measured on the UTBWC.

Replace the second and third paragraphs in section 3.E with the following:

Perform corrective work for ALR on the asphalt pavement before placing the UTBWC. No corrective work is allowed on the UTBWC. Any Mean Roughness Index (MRI) values for the 0.1 mile segments on the UTBWC indicating corrective work will be assessed a deduct of \$400 for each 0.1 mile segment.

H. Quality Control

The Contractor is responsible for obtaining all the quality control (QC/QA) sampling and testing as per the Materials Control Schedule.

I Polymer Modified Emulsion Membrane

Verify the application rate of the polymer modified emulsion membrane by dividing the volume of polymer modified emulsion membrane used by the area of paving for that day.

J. Quality Assurance

The Engineer is responsible for all quality assurance (QA) sampling according to Materials Control Schedule (MCS). The QA sample is the Department's companion sample to the Contractor's QC sample and tested as required.

J.1 Verification Sampling and Testing

The Department will test at a minimum one (1) verification sample per day to assure compliance of the Contractor's QC program. The Department will decide daily, which QC/QA companion samples are to be submitted and tested as the verification sample. The verification sample can be any one or all of the QC/QA split samples.

In addition the Engineer may obtain additional verification samples at any time and location during production to determine quality levels of the mixture. When additional verification samples are taken, the Department will provide the Contractor a verification companion. The contractor is required to 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.

Compare the verification companion sample to the verification sample for compliance with allowable tolerances in Table 2353-3, "UTBWC Allowable Difference between Contractor and Department Test Results". The Department's verification test results will be available to the Contractor within 2 working days from the time the sample is delivered to the District Laboratory.

If the tolerances between the Contractor's verification companion and the Department's verification sample do not meet the requirements of Table 2353-3, "UTBWC Allowable Difference between Contractor and Department Test Results", 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.

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.

If the adj. AFT calculation does not meet the tolerance in table 2353-3, equalize the Departments adj. AFT result by increasing the original Department value by 0.5 microns. The increased Department adj. AFT will be the basis for acceptance.

The Department will base acceptance on QC data with substitution of Department test results for those parameters that are 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.

Test	Item	Allowable Difference
Asphalt Binder	Chemical Extraction	0.4
	Incinerator Oven	0.3
Mixture max gravity (Gmm)	Rice Test	0.019
Adj. AFT (Calculated)		1.2
Gradation	% Passing	
	3/8 inch (9.5mm)	6%
	No. 4 (4.75mm)	5%
	No. 8 (2.36mm)	4%
	No.16 (1.18mm)	
	No. 30 (.060mm)	
	No. 50 (0.30mm)	3%
	No. 100 (0.150mm)	2%
No. 200 (0.075mm)	1.2%	

K. Failures

The Department will base material acceptance on individual test results and those exceeding the JMF limits as failing.

The Department will reduce payment for failing tests in accordance to Table 2353-4, "UTBWC Reduced Payment Schedule." 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 testing result is back within the JMF. 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.

If an individual failing test for % Asphalt Binder Content, adjusted AFT, or Gradation exceeds the limits in Table 2353-1, "UTBWC Mixture Requirements" or Table 3139-9, "UTBWC Aggregate Gradation Broadband then the mix will be subject to an assessment according to Table 2353-4, "UTBWC Reduced Payment Schedule"

Table 2353-4	
UTBWC Reduced Payment Schedule	
Item	Pay Factor ,% *
Asphalt Content, %	80
Adjusted AFT <10.5- 10.0	75 or ** (as determined by the Engineer)
Adjusted AFT <10.0	R & R**
Gradation	95
* Lowest Pay Factor applies when there are multiple reductions on a single test.	
** Remove and replace at no expense to Department	

The Department will reduce payment if the mat thickness is less than 5/8 inch [16 mm], or greater than 1 inch [25mm], or the pavement edge is greater than 1/2 inch [12.5 mm]. Any mixture placed outside of this requirement will be assessed a 50% pay reduction or remove and replaced, as determined by the Engineer, full width, by station.

2353.4 METHOD OF MEASUREMENT

Measure the Ultrathin Bonded Wearing Course by area of pavement surfaced.

2353.5 BASIS OF PAYMENT

Payment for the accepted quantity of Ultrathin Bonded Wearing Course at the Contract unit price of measure will be compensation in full for all costs of furnishing and applying all materials required in this specification. The unit price includes all labor, materials, and equipment necessary to complete the work.

Item No.:	Item:	Unit:
23535.504	Ultrathin Bonded Wearing Course	Square yard [square meter]

2354 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..... Bituminous Material

Provide a polymer modified CSS-1h for bituminous material for micro-surfacing in accordance with 3151.2H, "Micro Surfacing Emulsified Asphalt".

.....
B..... Aggregate

..... Provide aggregate in accordance with 3139.5, "Micro-Surfacing Requirements" and as specified in the Contract.

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 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 2354-1. Testing procedures may be obtained from the International Slurry Surfacing Association (ISSA).

Table 2354-1 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.

Submit a new mix design to the Engineer, if aggregate source, aggregate blend, or asphalt emulsion sources is changed.

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 (1 hour & 6 day),
 - (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 dual 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 FillType 3, per 3139.5

Rut fill pavement segments longer than 1,000 ft [300 m], if the average rut depth is greater than ½ in [13 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 [0.25 cm] per inch [centimeter] of rut depth to allow for proper consolidation by traffic.

B.1.b.....Scratch Course.....Type 2 or Type 3 per 3139.5, as shown on the plans

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.....Type 2, per 3139.5

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, asphalt emulsion source, or repairs are made to the aggregate feeding belt or gate.

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 [300 m] 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 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; the Engineer will evaluate whether any damage occurs. The Engineer will inspect the completed test strip again after 12 hr of traffic to determine if it is acceptable. The Contractor may begin full production after the Engineer accepts a test strip.

The Engineer may waive the test strip requirement, if the Contractor submits evidence of the successful construction of a test strip on another project constructed during the same construction season, using the same mix design.

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 and apply a CSS-1 or CSS-1h emulsion in accordance with 2355, "Bituminous Fog Seal," and the following:

- (1) 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].

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. Allow the fog seal to cure 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 mm] of the edge line, lane line, or center line, ensure the transverse cross section of the restored pavement surface is no greater than $\frac{3}{8}$ in [10 mm] if measured using a 10 ft [3 m] straight edge or $\frac{3}{16}$ in [5 mm] if measured with a 6 ft [2 m] straight edge.

Construct the surface course without excessive scratch marks, tears, rippling, and other surface irregularities. Repair tear marks wider than $\frac{1}{2}$ in [13 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 $\frac{1}{4}$ in [6 mm] if measured by a 10 ft [3 m] straight edge.

Construct longitudinal joints with no greater than $\frac{1}{4}$ in [6 mm] overlap thickness if measured with a 10 ft [3 m] straight edge, and less than 3 in [75 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 $\frac{1}{8}$ 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 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-hour 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-hour 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".

After successful completion of three, one-hour spot checks on the first day of production, the Engineer will perform spot checks once a day. If a 1-hour spot check fails, the Department will 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 and Time 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-hour of the planned micro-surfacing. Do not start work after September 15.

C..... Contractor Quality Control (QC) Testing and Documentation

Perform Quality Control (QC) sampling and testing.

C.1 Emulsion

Provide a material Bill of Lading (BOL) for each batch of emulsion used. Include the supplier's name, plant location, emulsion grade, residual asphalt content, volume (gross and net, gallons) and batch number.

C.2 Aggregate

Sample and test according to the Schedule of Materials Control. Provide QC test results daily to the Engineer and a summary upon completion of the work.

C.2.a Gradation and JMF Tolerance

Provide companion samples to the Engineer. The QC tolerances for the JMF are listed in Table 3139-10. The tolerance range may not exceed the limits set per 3139.5.

C.2.b..... Sand Equivalent Test

The Sand Equivalent 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.

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.

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.

D..... Agency Quality Assurance (QA) Testing

Sample and test the following according to the Schedule of Materials Control.

1. Asphalt Emulsion,
2. Aggregate Gradation
3. Moisture Content of the Aggregate

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

A.....Monetary Price Adjustments

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 per 2354.3B4 or 2354.3B7. If the test strip fails, the Department will deduct \$5,000 from the contract amount.

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.

2355.2 MATERIALS

Bituminous Material

Provide bituminous emulsion as shown in the plans meeting the following requirements of 3151.

- (1) CSS-1h diluted to a ratio of one part water to one part emulsion (3151.2.D.1), or
- (2) CRS-2Pd (3151.E.2).

Dilute during manufacture. Do not dilute in the field.

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 bituminous fog seal as shown in Table 2355-1, Fog Seal Application Rates, and within the temperatures specified in Table 2355-3, Fog Seal Application Temperatures.

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.

Using a distance of 1,000 feet [300 meter] perform a yield check at the beginning of each project to verify the application rate is correct. The Engineer may require additional yield checks be performed if the application rate is questioned. The Engineer may also require the Contractor to verify application is within 10% of the intended application rate by ASTM D 2995 test method A.

Table 2355-1 Fog Seal Application Rates	
Application Rates -- gallons/square yard [liters/square meter]	
CSS-1h	CRS-2Pd
0.05 to 0.20 [0.23 to 0.91]	0.05 to 0.20 [0.23 to 0.91]

Table 2355-2 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:
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2355.502	Bituminous Material for Fog Seal	gallon [liter]
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2356 BITUMINOUS SEAL COAT

2356.1 DESCRIPTION

This work consists of applying bituminous material, a single layer of aggregate, and a fog seal on a prepared surface.

2356.2 MATERIALS

A..... Bituminous Material

Provide CRS-2P bituminous material for seal coat meeting the requirements of 3151, "Bituminous Material":

Provide diluted CSS-1h bituminous material for fog seal meeting the requirements of 3151, "Bituminous Material".

B..... Seal Coat Aggregate

Provide aggregate meeting the gradation, job mix formula tolerance and quality requirements of Tables 3127-1 and 3127-2, for the gradation specified in the Contract. If no requirements are specified in the Contract, provide aggregate meeting the requirements of Tables 3127-1 and 3127-2 for FA-3.

C..... Blank

D..... Water

Use potable water compatible with the seal coat and meeting the requirements of 3906, "Water for Concrete and Mortar".

E..... Seal Coat Design

Use the Minnesota Seal Coat Handbook, MN/RC-2006-34 available on the MnDOT website, to design the seal coat and determine the starting application rate for the bituminous material and seal coat aggregate. Base the mix design on the traffic volume and pavement conditions.

Provide the following to the Engineer at least 2 weeks before beginning construction:

- (1) Gradation and quality test results as specified in 3127.3,
- (2) Seal coat aggregate design application rate,
- (3) Bituminous material design application rate and
- (4) 150 lb [70 kg] sample of aggregate from each proposed aggregate source.

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 considers the seal coat's design aggregate application rate as a target amount.

2356.3 CONSTRUCTION REQUIREMENTS

A..... Weather, Time and Date Limitations

Apply the bituminous seal coat in accordance with the following:

- (1) From May 15 to August 10, if located in the North or North-Central Road Spring Restriction Zone (Zones are defined on the MnDOT Pavement Design Website),
- (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° F [15.5° C] 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 design 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 applying 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 mix design. Construct a test strip 200 ft [60 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
CRS-2P	140 F [60 C]*
CSS-1h	100 F [38 C]
* Intended for uniform lay down of emulsion	

E Application of Seal Coat

Before construction, calibrate the aggregate spreader to meet the requirements of ASTM D 5624, in the presence of the Engineer. Maintain the aggregate application rate within ± 1 lb per square yard [± 0.5 kg/m²] of the design.

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

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 by all the rollers.

G.....Sweeping

Remove 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 rolling is completed and the bituminous material has set.

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 applies the permanent pavement markings, the Contractor's responsibility ends after completion of the fog seal and placement of temporary pavement markings.

J.....Application of Bituminous Material for Fog Sealing

Apply fog seal to seal coated areas, after sweeping and before placement of permanent pavement markings.

Apply the fog seal in accordance with 2355, "Bituminous Fog Seal," and as modified as follows:

- (1) Construct a 200 ft [60 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.

L.....Contractor Quality Control Testing

Sample and test according to the rates in the Schedule of Materials Control.

Submit test results to the Engineer within 24 hours of test completion.

Verify and report the average daily bituminous material application rate by dividing the volume used by the area covered.

If gradations fall outside of the Job Mix Formula Tolerance of Table 3127-1, but within specifications, stop placement and submit a new mix design.

M Agency Quality Assurance (QA) Sampling and Testing
Sample and test according to the rates in the Schedule of Materials Control.

2356.4 METHOD OF MEASUREMENT

The Engineer will measure the bituminous material for fog seal by volume, at 60° F [15° C], undiluted. Conversion factors are located in the MnDOT Bituminous Manual. 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 [square meter] 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 all applied aggregate.

A.....Monetary Price Adjustments

The Engineer may allow the Contractor to accept a monetary price adjustment instead of removing and replacing failing materials in accordance with the following:

- 1) The Department will assess a monetary price adjustment of \$2,000 for each failing QA flakiness test.
- 2) The Department will reduce the contract unit price for bituminous seal coat by 0.5 percent for each 1 percent passing outside of the requirements for any sieve as specified in 3127, "Fine Aggregate for Bituminous Seal Coat", except for the #200 sieve, as determined by QA testing.
- 3) The Department will reduce the contract unit price for bituminous seal coat by 2 percent for each 0.1 percent passing outside of the requirements for the #200 sieve as specified in 3127, "Fine Aggregate for Bituminous Seal Coat", as determined by QA testing..

The monetary price adjustment for 2356.5A2 and 2356.5A3 are based upon the contract bid price for bituminous seal coat, however if the contract bid price is less than 75% of the Department's average bid price for bituminous Seal Coat, the Engineer may use the average bid price to assess the monetary price adjustment.

The Department will add the monetary price adjustments for all failing test results together.

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 applying bituminous material (emulsion or cutback asphalt) on a bituminous or concrete pavement prior to paving a new lift of Plant Mixed Asphalt.

2357.2 MATERIALS

A Bituminous Material 3151

The bituminous material for tack coat will be limited to one of the following kinds of emulsified asphalt. Use of medium cure cutback asphalt (MC-250) is allowed during the early and late construction season when it is anticipated the air temperature may drop below 32 degrees Fahrenheit.

Allowable grades are as follows:

Emulsified Asphalt

AASHTO 208 Dilution of the emulsion to 7 parts emulsion to 3 parts water is only allowed by the supplier. **No field dilution is allowed.** The storage tank for diluted emulsion must have a recirculation system or agitator that will prevent settlement or separation of the material.

Table 2357-1 Residual Asphalt Content		
	Minimum Residual Asphalt Content	
Emulsion	Undiluted	Diluted (7:3)
CSS-1 or CSS-1h	57%	40%

Cutback Asphalt

Medium Cure Liquid Asphalt MC-250

Only Certified Sources are allowed for use. MnDOT's Certified Source List is located at the following link: <http://www.dot.state.mn.us/products/index.html>.

2357.3 CONSTRUCTION REQUIREMENTS

A Restrictions

Conduct tack coat operations in a manner that offers the least inconvenience to traffic. Maintain movement in at least one direction at all times without pickup or tracking of the bituminous material.

Do not apply the tack coat when the road surface or weather conditions are unsuitable as determined by the Engineer. Limit the daily application of tack coat to approximately the area on which construction of the subsequent bituminous course can reasonably be expected to be completed that day.

B Equipment

Apply the bituminous material with a distributor meeting the requirements of 2360.3.B.2.d.

C Road Surface Preparations

Apply the bituminous tack coat material to a dry and clean roadway surface. All necessary repairs or reconditioning must have been completed as provided for in the Contract and approved by the Engineer.

Remove all foreign matter on the road surface before applying tack coat and dispose of as approved by the Engineer.

Before placing an abutting bituminous course, provide a uniform coating of liquid asphalt or emulsified asphalt to the contact surfaces of all fixed structures and at the edge of the in-place mixture in all courses at transverse joints and in the final wearing course at longitudinal joints.

D Application of Bituminous Tack Coat Material

Unless otherwise indicated in the Plans or provisions, apply the bituminous tack coat material within the application rates shown below in Table 2357-2, Tack Coat Application Rates, as based on pavement type or condition and type of bituminous material. **Dilution of asphalt emulsion in the field is not allowed.**

All tack must break, turn from brown to black, before paving the subsequent lift or course. Do not allow vehicles to drive on tack that has not broken.

Apply a uniform tack coat to the existing asphalt or concrete surface and to the surface of each course or lift constructed, except for the final course or lift. Tack each lift when placing multiple lifts in the same day. Uniform application will not have streaks (corn rows), bare spots, puddles, or other irregular patterns. The Engineer will compare the freshly sprayed emulsion to a brown sheet of construction paper or a black sheet of construction paper for broken tack to determine conformance with tack application uniformity.

Using a distance of 1,000 feet [300 meter] perform a yield check at the beginning of each project to verify the application rate is correct. The Engineer may require additional yield checks be performed if the application rate is questioned.

The Engineer may also require the Contractor to verify application is within 10% of the intended application rate by ASTM D 2995 test method A.

Table 2357-2 Tack Coat Application Rates			
Application Rates -- gallons/square yard [liters/square meter]			
Surface Type	Undiluted Emulsion	Diluted Emulsion (7:3) ¹	MC Cutback ²
New Asphalt	0.05 to 0.07 [0.23 to 0.32]	0.08 to 0.10 [0.36 to 0.45]	0.05 to 0.07 [0.23 to 0.32]
Old Asphalt ³ and PCC	0.08 to 0.10 [0.36 to 0.45]	0.13 – 0.15 [0.59 to 0.68]	0.09 to 0.11 [0.41 to 0.50]
Milled Asphalt and Milled PCC	0.07 to 0.11 [0.41 to 0.50]	0.10 – 0.13 [0.45 to 0.59]	0.09 to 0.11 [0.41 to 0.50]

- 1- As provided by the asphalt emulsion supplier (see 2357.2.A)
- 2- Use when approved by the Engineer
- 3- Older than 1 year

E Bituminous Temperature

The application temperature of the bituminous material will be:

CSS-1, CSS-1H 70 to 160° F (21 to 71°C)

MC-250 165 to 220° F (74 to 104°C)

F Bituminous Sampling

Sample asphalt emulsion from either the spigot or a nozzle on the distributor according to the schedule of materials control.

G Pedestrian Crossings

Spread sand on newly tacked surfaces at regularly utilized and open for public use pedestrian crossings.

H Acceptance of Tack Material

Assess a monetary deduction of 5% of the mix price for failures related to 3151 or workmanship/application, as determined by the Engineer. The basis of measurement for deficiencies related to material and workmanship/application is full width of the lane by station.

2357.4 METHOD OF MEASUREMENT

Bituminous material used for tack coat will be measured by volume at 15°C (60° F).

2357.5 BASIS OF PAYMENT

Payment for the accepted quantity of asphalt emulsion and cutback shall be at the Contract price per unit of measure for undiluted asphalt emulsion and neat cutback. The Department will include the cost of providing and applying sand at pedestrian crossings with other relevant contract items.

Payment for the tack coat will be made 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 surface.

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 = ¾ in [9.5mm], SP 4.75.
- (4) The sixth digit indicates the Traffic Level (ESAL's × 10⁶) in accordance with Table 2360-1, "Traffic Levels."

Traffic Level	20 Year Design ESALs
2 *	< 1
3	1 – < 3
4	3 – < 10
5	10 – < 30
6	>30 (See SMA Provision)
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 (ESAL's) 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 wear mixtures, and
 - (5.2) 30 = 3.0 percent for 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."

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
I	PG 70 – 34
L	PG 64 – 22
M	PG 49 – 34

Ex: Gyratory Mixture Designation -- SPWEB540E (Design Type, Lift, Aggr. Size, Traffic Level, Voids, Binder)

2360.2 MATERIALS

A Aggregate

Use aggregate materials in accordance with 3139.2.

B Asphalt Binder Material 3151

C Additives

The Department defines additives as material added to an asphalt mixture or material that does 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. 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 an anti-strip agent is added at the plant, the plant mixed asphalt producer is considered a supplier and the binder must conform to the requirements of 3151. 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 shear 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 MnDOT 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 MnDOT 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.

C.3 Coating and Anti Stripping Additive 3161

C.4 Warm Mix Asphalt (WMA)

WMA is allowed on all projects. Any mix that is produced at temperatures 30°F or lower than typical HMA mixing temperature of the asphalt binder, as defined by the asphalt supplier, is considered as WMA. The WMA can be manufactured through use of foamed asphalt and/or chemical additive processes. Notify the Engineer in advance of using any WMA additive or process. When chemical additives are used, provide the plant mixing and the laboratory mixing and compaction temperatures as recommended by the manufacturer of the additive.

D Bituminous Tack Coat ... 2357

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.

E.3 Restrictions

Do not add aggregates and materials not included in 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) MnDOT Laboratory Manual Method 1820,
- (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 aggregate samples for option 1, 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, "Bituminous Aggregates." 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 minutes 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 in the MnDOT Laboratory Manual Method 1813.

E.5.a(6) Aggregate Specific Gravity

Determine the specific gravity of aggregate in accordance with Laboratory Manual Methods 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 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.

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) Initial Production Test Verification

The Department will take a mix verification sample within the first four samples at the start of production of each mix type. The Engineer will notify the Contractor electronically when a sample is to be taken and tested for tensile strength ratio (TSR). Initial production testing will be done within the first 5,000 tons [4500 tonnes] of the start of production.

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
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.I, "Field Tensile Strength Ratio (TSR)."				
MnDOT minimum = 65				
† MnDOT minimum = 70				

E.7 Minimum Ratio of Added Asphalt Binder to Total Asphalt Binder

Control recycled materials used in mixture by evaluating the ratio of new added asphalt binder to total asphalt binder as show in Table 2360-8.

Table 2360-8 Requirements for Ratio of Added New Asphalt Binder to Total Asphalt Binder¹ min%:			
Specified Asphalt Grade ²	Recycled Material		
	RAS Only	RAS + RAP	RAP Only
PG XX-28, PG 52-34, PG 49-34, PG 64-22			
Wear	70	70	70
Non-Wear	70	70	65
PG 58-34, PG 64-34, PG 70-34			
Wear & Non-Wear	80	80	80
¹ The ratio of added new asphalt binder to total asphalt binder is calculated as (added binder/total binder) x 100			
² The Contractor can elect to use a blending chart to verify compliance with the specified binder grade. The Department may take production samples to ensure the asphalt binder material meets the requirements. The blending chart is on the Bituminous Office Website.			

E.8 Adjusted Asphalt Film Thickness (Adj. AFT) MnDOT Laboratory Manual Method 1854

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.

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 and compaction,
 - (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 Mn/DOT 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:
 - (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/Ae (Fines to effective asphalt ratio).
 - (13.10) Gyrotory densification tables and curves generated from the gyrotory compactor for all points used in the mixture submittal.
 - (13.11) % new asphalt binder to total asphalt binder.
- (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) Up to two add materials will be allowed.

F Mixture Design Report

The Department will 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 broadbands shown in Table 3139-2, 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 shown in Table 2360-7 and Table 2360-8. The Department makes no guaranty or warranty, either express or implied, that compliance with volumetric properties ensures specification compliance 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 all paving except for small quantities of material as described in 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)

The Contractor will perform Quality Control (QC) as part of the production process. QC is the process control of the operations related to mixture production and determining the quality of the mixture being produced. The QC sample is the Contractor's sample taken and tested during production and used to control the production process. 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 sections 1200, 1800, and 2000 of the Mn/DOT Laboratory Manual.
- (4) A Department-signed Mixture Design Report (MDR) before mixture production.

G.1.b Maintaining Certification

Maintain plant certification by documenting the production 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 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, 2360.2.E7, and 3139.2,
- (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) as part of the acceptance process. QA is the process of monitoring and evaluating various aspects of the Contractor's testing as described below. The QA sample is the Department's companion sample to the Contractor's QC sample. QA testing is performed 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.

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
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 minimum of one of the companion samples to the Contractor's QC samples and identify this as a verification sample. The Department's verification sample is used to assure compliance of the Contractor's QC program. The verification samples can be any one or all of the splits to the Contractor's QC samples. Additionally, the Department can take a random sample at any time from behind the paver or from the truck box and will consider this a verification sample. The split of this sample, given to the Contractor, must be tested by the Contractor and will 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, Table 3139-3, and Table 2360-7. 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 2360.2.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, within 2 working days from the time the sample is delivered to the District Laboratory. The Department will provide the gradation, crushing, and Adj. AFT (calculated) 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 immediately 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. The process for dispute resolution is available on the Bituminous Office website.

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 through analysis of data, it is determined that there is a bias in the test results, 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 MnDOT 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 2010 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 tonnage or locations, quartered from a larger sample of mixture. Sample randomly and in accordance with the Schedule of Materials Control. Determine random numbers and tonnage or locations using the Bituminous Manual; Section 5-693.7 Table A or ASTM D 3665, Section 5, or, an Engineer approved alternate method of random number generation. Sample either behind the paver or from the truck box at the plant site. Other sampling locations can be approved by the Engineer. The Contractor must decide and notify the Engineer where samples will be taken before production begins. The Contractor and Engineer must both agree to a change of sampling location once production has begun. The procedure for truck box sampling is on the Bituminous Office website. The Contractor will obtain at least a 130 pound [60 kg] sample. Split the sample in the presence of the Inspector. The Inspector will retain possession of the Agency portion of each split sample that is taken and randomly submit a minimum of one sample, on a daily basis, to the District Laboratory for Verification testing (see 2360.2.G.3). Store compacted mixture specimens and loose mixture companion samples for 10 calendar days. Label these split companion samples with companion numbers.

If coarse and fine aggregate angularity are not evaluated for every QC sample retain the extracted gradation samples for the respective QC samples for additional testing. Keep the aggregate samples in containers with field identification labels for a period of 10 calendar days. The Engineer will identify which extracted gradation sample is the Verification Companion and whether it is to be tested for coarse and fine aggregate angularity.

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 MnDOT 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.5a Establishing an Ignition Oven Correction Factor MnDOT Lab. Manual 1853 Appendix

On the first day of production, for each mixture type, both the Contractor and the Agency will establish an ignition oven correction factor from the produced mixture. Re-establish correction factors when:

There are aggregate or RAP substitutions

There are 3 or more tolerance failures on the extracted asphalt content between the Agency 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	<u>Testing Rates</u>	<u>Laboratory Manual Method</u>	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 1000 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]	1206	2360.2.G.7.h
Fines to Effective Asphalt Ratio (calculated)	1 test per 500 ton [450 tonne]	1203 & 1853	2360.2.G.7.f & 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
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 1,000. 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
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 1206	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 & 1853	2360.2.G.7.f & 2360.2.G.7.a
TSR	As directed by the Engineer	Laboratory Manual 1813	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 1855	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]	MnDOT Bituminous Manual 5-693.920	2360.G.7.l

G.7 Production Tests

G.7.a Asphalt Binder Content

Spotchecks are required only when the Engineer has waived the requirements of 2360.2G8 relating to furnishing a computerized printout of the plant blending control system. A minimum of 1 spotcheck per day per mixture blend is required 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.

G.7.b Gyrotory Bulk Specific Gravity, Gmb

Use two specimens to determine gyrotory bulk specific gravity meeting the requirements of Laboratory Manual Method 1806. Set Gyrotory to an internal angle of $1.16^\circ \pm 0.02^\circ$ according to AASHTO TP 71.

G.7.c Maximum Specific Gravity, Gmm

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 gyrotory 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.

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. 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 1206 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. 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. 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:

- (1) Date,
- (2) Time,
- (3) Project number, and
- (4) 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. 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). Take mixture samples from the windrow or truck box. 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.

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. 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	MnDOT	Contractor	MnDOT
75	65	80	70

Table 2360-13			
Anti-Strip Cost Responsibility			
Gyratory Level	Contractor TSR	MnDOT 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 the Bituminous Office website.

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, if approved by the Engineer, in the truck box. Sample and test as 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

Obtain asphalt binder samples from a sampling valve located between the pump and the drum. Sample each type of asphalt binder used in mixture production after 50 tons of mixture has been produced, then sample at a rate of one per 250,000 gal [1,000,000 L]. A minimum of 1 gallon of binder must be drawn and wasted from the sampling valve before the actual sample is drawn. For batch plants, obtain the asphalt binder sample from the weigh pod. Provide a 1 qt [1.0 L] sized sample. The Inspector will monitor the sampling the Contractor performs.

Record sample information on an Asphalt Sample Identification Card. Submit the sample to the Central 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 % 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 MnDOT and Contractor Representative,
- (16) Mixture Moisture Content, and
- (17) MnDOT verification sample test result.
- (18) Identify, when used, the WMA additive or process and dosing rates.

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.

Provide a final hard and electronic copy of QC test summary sheets and control charts, and density worksheets at completion of bituminous operations on the project to the Engineer.

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.

Furnish an electronic printout (long form recordation) from an automated plant blending control system at 20 minute intervals when the plant is producing mixture. The Engineer may waive this requirement if the plant does not have the capability to produce the automated blending control information; however, the Contractor must then perform daily spotchecks to determine percent new asphalt added.

Include the following information on the plant control printout for Drum Plants:

- (1) Both the virgin and recycle belt feed rates (tons/hr),
- (2) Feeder bin proportions (%),
- (3) Total % asphalt cement in the mixture,
- (4) Virgin asphalt cement added (%)
- (5) Mixture Temperature °F [°C],
- (6) Mixture code,
- (7) Date and time stamp, and
- (8) Current tons of mixture produced and daily cumulative tons of mixture produced at time of printout.

Provide a daily electronic printout of the plant calibration (SPAN) numbers for each bin and meter.

Include the following information on the plant control printout for Batch Plants:

- (1) Both the virgin and recycle belt feed rates (tons/hr),
- (2) Feeder bin proportions (%),
- (3) Mixture Temperature °F [°C],
- (4) Mixture code,
- (5) Date and time stamp, and
- (6) Current tons of mixture produced and daily cumulative tons of mixture produced at time of printout.

Provide a daily electronic printout of the plant calibration (SPAN) numbers for each bin and meter.

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 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. 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.

Item	JMF Limits
Adj. AFT	- 0.5
Production air voids, %	\pm 1.0
Asphalt binder content, %	- 0.4
<i>Sieve, % passing:</i>	
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 Mixture Design Report, and the JMF limits.

G.13 JMF Adjustment

Begin mixture production with aggregate proportions within 5 percent of the design proportions and mixture parameters in Table 2360-14 within the JMF limits shown. Use all the aggregate proportions included on the Mixture Design Report unless the aggregate proportion is shown as 0 percent. 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 waive the preceding requirements.

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 Department 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 3139-3, "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 broadbands in accordance with Table 3139-2. Submit a new JMF if redesigning the mixture. Only reduce the JMF asphalt content if the moving average Adj. AFT is 8.5 μ or more and Individual Adjusted AFT is 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 design requirements as discussed in G.13.a, 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 design requirements, 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.13.c JMF Request for Adjustment When Cumulative Proportion Changes > 10%

Submit a request for JMF adjustment when the cumulative change on any one product exceeds 10% from the original MDR. The Department will issue a revised MDR provided the mixture meets the requirements in Table 3139-2, "Aggregate Gradation Broad Bands", Table 3139-3, "Mixture Aggregate Requirements", and Table 2360-7, "Mixture Requirements".

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 exceeding 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

Minimum design ratio of new added asphalt binder to total asphalt binder is shown in Table 2360-15 below. During production the ratio must meet individual and moving average requirements as listed in 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, the Contractor must stop production and make adjustments to correct the process. Restart production only after notifying the Engineer of the adjustments made. The calculation of the moving average will continue after the stop in production.

Table 2360-15			
Ratio of New Added Asphalt Binder to Total Asphalt Binder Acceptance Criteria			
Specified Asphalt Grade	Recycled Material		
	RAS Only	RAS + RAP	RAP Only
PG XX-28, PG 52-34, PG 49-34, PG 64-22 Wear (ind./moving average)	66/70	66/70	66/70
Non-Wear (ind./moving average)	66/70	66/70	61/65
PG 58-34, PG 64-34, PG 70-34 Wear & Non-Wear (ind./moving average)	76/80	76/80	76/80

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 less 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 – Percent Asphalt Binder, Production Air Voids, and Adj. AFT

Table 2360-16	
Reduced Payment Schedule for Individual Test Results	
<u>Item</u>	Pay Factor, % *
Coarse and fine aggregate crushing	90
Asphalt binder content	90
Production air voids, individual and isolated†	80
* Apply the lowest pay factor 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.	

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 expense 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 less 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, 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 equipment. An asphalt release agent must meet the criteria for "Effect on Asphalt" as described in the most recent Asphalt Release Agent on file in MnDOT's Office of Environmental Services.

A.2 Edge Drop Off

When construction is under traffic, the requirements of 2221.3.D 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 at 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 or moisture conditions of the roadway surface are judged unfavorable by the Engineer.

Do not place asphalt pavement final wearing course lift 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.

A.5 Mixing and Discharge of Materials

Notify the Engineer of the recommended plant mixing temperatures as provided from the asphalt supplier. Unless authorized by the Engineer, do not produce the mixture more than 30°F above the recommended maximum mixing temperature. Use the automated plant control printout to monitor discharge temperature. The Department will not pay for or allow placement of any mixture produced at more than 30°F above the recommended maximum mixing temperature unless the higher mixing temperatures have been approved by the Engineer.

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.

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.e (1) Asphalt Binder Sampling Valve

Provide an asphalt binder sampling valve located between the pump and the drum. Sample asphalt binder from the weigh pod for batch plants.

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.1.h. Pollution..... 1717

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, when 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 (excluding tight blade and scratch course applications). 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 ½ in [13 mm] or less,
- (3) Equipped with a moldboard blade that is at least 10 feet [3 m], and
- (4) With a wheelbase of at least 15 feet [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

Compact each lift of asphalt to the density require in 2360.3.D, "Compaction."

B.2.e(1) Steel-Wheeled Rollers

Self-propelled steel wheeled compacting equipment must weigh 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

Self-propelled pneumatic tired compacting equipment must have a compaction 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

Self-propelled trench rollers must weigh at least 2,960 lb per foot [4,400 kg per meter] of width.

B.3 Tack Coat

Apply a uniform asphalt tack coat to the clean and dry existing asphalt or concrete surface and to the surface of each course or lift constructed, except for the final course or lift, in accordance with 2357. Coat the contact surfaces of all fixed structures and the edge of the in-place mixture in all courses at transverse joints and in the wearing course at longitudinal joints. Do not coat the longitudinal joint if a rubberized asphalt joint adhesive will be applied to the vertical face of the joint. A uniform application will not have streaks (corn rows), bare spots, puddles, or other irregular patterns. Allow emulsified asphalt tack coats to break, as indicated by a color change from brown to black, before placing subsequent lifts. Take tack samples from the asphalt distributor according to rates provided in the Material Control Schedule. The Inspector will monitor the sampling the Contractor performs.

C Joints

C.1 Construction Joints

Compact joints to produce a neat, tightly bonded joint that meets surface tolerances as described in 2360.3.E. 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. The Contractor will 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 $\frac{1}{8}$ 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 as described in 2360.3.D.1, 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 Wear Mixtures*	SP Non-Wear Mixtures*	SP Shoulders*	
			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)	89.5	88.1
Long joint non-wear and shoulder (3% air voids)	90.5	89.1
* 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 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 Density Determination (Core Bulk Density)

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. Use Laboratory Test Method 1810 to determine core density unless the mixture is considered coarse graded. If 45 percent or less of the aggregate material passes the No. 4 [4.75 mm] sieve the Engineer may require bulk specific gravity be determined in accordance with Laboratory Manual Method 1816, Corelok.

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 between 6 h and 8 h after mixture placement. Do not reroll compacted mixtures with deficient densities.

D.1.f Stop Production

If all the lots in a day's production or greater than 50 percent of the lots on multiple days fail to meet the minimum density requirement stop production and determine the source of the problem. Discuss with the Engineer what corrective action will be taken 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 tons [820 tonne] or part thereof.	

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 taking care to prevent damage to them. 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 gravity between the Contractor and the Department cores differ by more 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 Recoring

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 elect 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. The Contractor must notify the Engineer, in writing, after the first day's paving and by the end of the third day of paving of their intent to waive reduced density. Once reduced density has been waived the normal maximum density will remain in effect for the duration of mixture placement on that lift. For multi-year projects, the waiving of reduced density will be for that year only and will be re-evaluated for subsequent years on an annual basis. The Contractor is required to 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 Shoulders (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 in the lot 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 G_{mm} , the Engineer will decide if the mixture is subject to removal and replacement or if will be accepted at a reduced payment of 50 percent of the relevant contract unit price. If the Engineer decides the material is to be removed and replaced, the Contractor will do so at no additional cost to the Department. Take additional core samples to determine the limits of the removal and replacement area or 50% payment using 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 the 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 (>89.0% for 4% void and 1% reduced voids and >90.0% for 3% voids). If the 50 ft (15 m) incremental testing extends into a previously accepted lot, removal and replacement may be required, but, these results will not be used to recalculate the previously accepted lot density.

Perform the additional coring and testing at no 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.

Establish an additional density lot for the pavement that has been removed and replaced. Cut 2 cores randomly with companions for the Department (total 4 cores) and determine average density. Make payment in accordance with Table 2360-22 or Table 2360-23 excluding any incentive payment.

Determine the density for the remainder of the lot by averaging the original acceptable core density value with the first two acceptable core densities taken ahead and behind the unacceptable core density. Make payment in accordance with Table 2360-22 or Table 2360-23 excluding any incentive payment.

Table 2360-23*		
1 Percent Reduced Table		
SP Wear and SP Shld (4% Void) Maximum Specific Gravity, % 	SP Non-Wear, and SP Shld (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 in-place 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 by 1 percent on the first lift constructed on PCC pavements (reduced density cannot be waived on PCC).

|| 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 in the lot 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 G_{mm} , the Engineer will decide if the mixture is subject to removal and replacement or if will be accepted at a reduced payment of 50 percent of the relevant contract unit price. If the Engineer decides the material is to be removed and replaced, the Contractor will do so at no additional cost to the Department. Take additional core samples to determine the limits of the removal and replacement area or 50% payment using 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 the 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 (>89.0% for 4% void and 1% reduced voids and >90.0% for 3% voids). If the 50 ft (15 m) incremental testing extends into a previously accepted lot, removal and replacement may be required, but, these results will not be used to recalculate the previously accepted lot density. Perform the additional coring and testing at no 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.

Establish an additional density lot for the pavement that has been removed and replaced. Cut 2 cores randomly with companions for the Department (total 4 cores) and determine average density. Make payment in accordance with Table 2360-22 or Table 2360-23 excluding any incentive payment.

Determine the density for the remainder of the lot by averaging the original acceptable core density value with the first two acceptable core densities taken ahead and behind the unacceptable core density. Make payment in accordance with Table 2360-22 or Table 2360-23 excluding any incentive payment.

Table 2360-24*					
Payment Schedule for Longitudinal Joint Density (SP Non-wear and SP Shoulders, 4% Void)					
Longitudinal Joint (Confined Edge) Density, % 	Pay Factor B Longitudinal (Confined Edge)		Longitudinal Joint (Unsupported Edge) Density, % 	Pay Factor C (Unsupported Edge)	
	Traffic Level 2 & 3	Traffic Level 4 & 5		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)					
Longitudinal Joint (Confined Edge) Density, % 	Pay Factor B Longitudinal (Confined Edge)		Longitudinal Joint (Unsupported Edge) Density, % 	Pay Factor C (Unsupported Edge)	
	Traffic Level 2 & 3	Traffic Level 4 & 5		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 and practices.
- (7) Bike paths, walking paths, and other similar non-traffic paving areas

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. 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, "Minimum 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.

<u>Air</u> 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.				

D.3 Mat Density Cores (Optional Department Only Core Testing)

The Contractor can request all density cores be tested by the Department. The written request should be made at the pre-construction meeting and a written response, from the Department, either approving or denying the request will be made within 5 calendar days from the date of the request. Once approval is granted, Department Only Core Testing will remain in effect for the duration of the project. For multi-year projects, Department core testing will be for that year only. Cores will be tested in either the Department's Field Lab or in the Contractor's Field Lab. The Contractor is permitted to observe and record all weighing of the cores.

D.3.a Contractor Coring Responsibilities

Obtain two cores in each lot. Take cores of at least 4 in [100 mm] in diameter at locations determined and marked by the Engineer. 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. Label samples with the lot number and core number or letter. The Contractor is responsible for maintaining traffic, coring, patching the core holes.

Measure each core three times for thickness before saw cutting. Report the average lift thickness to the Engineer. If placing multiple layers in a single day, measure and record lift thickness and then saw and separate cores for each layer. 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.

The Engineer may require additional density lots to isolate areas affected by equipment malfunction, heavy rain, or other factors affecting normal compaction operations.

D.3.b Department Testing Responsibilities

The Department will take possession of the cores after they have been measured and cut. The Department will test all cores. Density results will be determined by the end day in which the cores were cut provided they are in the Department's possession by 10:00am, otherwise, results will be available the next working day. Test results will be reported on the Core Density Sheet.

D.3.c 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 three 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 one core 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.

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 2360-26 Surface Requirements		
Course/Location	Description	Tolerance
Leveling/1 st lift using automatics	Tolerance also applies to 1 st 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 foot [3 m] straightedge laid parallel to or at right angles to the centerline.	¼ in [6 mm]
Shoulder Wear, Temporary Wear & bypasses	Tolerance from the edge of a 10 foot [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 foot [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 inches [75 mm] greater than the plan distance. The edge alignment of the wearing lift on tangent sections and on curve sections of 3 degrees or less can't deviate from the established alignment by more than 1 inch [25 mm] in any 25 foot [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 1/4" [6mm] than the concrete surface.	See Description
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 not to exceed 1/4" [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. *Excluding tight blade and scratch courses.	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.

In addition to the list the above the pavement surface must meet requirements of 2399 (Pavement Surface Smoothness) requirements.

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. The Engineer may require removal and replacement of any part of any lift that is constructed to less than the minimum required thickness, 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 exceed 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 or 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

A MDR is not required for planned project quantities less than 9,000 sq. yd inches (4,500 sq. yd per 2-inch thickness, etc) [191,200 m² 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.G.14.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. Anti-stripping additives may be permitted or required as indicated in 2360.2.C.

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 1403, "Extra Work."

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:

$$\% \text{ Payment} = \frac{100 - (100 \times (\text{production_density_at_design_gyrations} - 160))}{160}$$
$$\left[\% \text{ Payment} = \frac{100 - (100 \times (\text{production_density_at_design_gyrations} - 2,565))}{2,565} \right]$$

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 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 2360.1.A.3.	
	"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.	

2363 PERMEABLE ASPHALT STABILIZED STRESS RELIEF COURSE (PASSRC) AND PERMEABLE ASPHALT STABILIZED BASE (PASB)

2363.1 DESCRIPTION

PASSRC is typically constructed on the in place concrete or bituminous surface to act as a separation layer and move water rapidly from beneath the unbounded concrete overlay for greater service life.

PASB is typically constructed on a prepared base under a new concrete or bituminous surface to quickly drain surface infiltrated water accumulating under the pavement.

2363.2 MATERIALS

A Aggregate.
Use MnDOT 3139.3.

B Asphalt Binder
Use MnDOT 3151.A (PG 64-22)

C. Mixture Design

C.1 Sample submittal

At least 15 days prior to the beginning of mixture production, submit representative samples of aggregate and the asphalt binder to perform the PASSRC or PASB mix design in District Materials Lab where the project is located. Submit aggregates that require magnesium sulfate soundness at least 30 days prior to the start of asphalt production.

C.2 Aggregate

1. Submittal. Submit to the District Materials Engineer an 80 lb [35 kg] sample of aggregate retained on the #4 [4.75 mm] sieve and 35 lb [15 kg] of aggregate passing the #4 [4.75 mm] sieve. The Contractor will obtain and store an equal size sample until the Mixture Design Report (MDR) is issued.
2. Intent to Sample. Provide the agency with 24 hour advance notification.

3. Testing. Test for the quality of each source, class, type and size of virgin and non-asphaltic salvage aggregate source will be done for the mix design.

C.3 Asphalt Binder

1. Submittal. Submit 4- 1 quart [1.0 L] samples of the same PG grade as required and also from the same supplier as production will come from.

C.4 Mixture

Provide the proposed Job Mix Blend for each combination of aggregates to be used in the mixture. Include the following information:

1. Composite gradation. Based on the proportions of each material, determine the composite gradation in percent of total aggregates.
2. Individual gradation. Determine the gradation for each individual component.
3. Source. Document the aggregate source, pit number, and a description of all materials.

C.5 Mixture Design Report (MDR)

The Engineer will issue an MDR when the mixture design is successfully completed. The MDR will include the Job Mix Formula (JMF) requirements for gradation and asphalt cement content. Paving without an MDR is not allowed.

D. Mixture Quality Management.

D.1 Sampling and Testing

Production sampling and testing rates for start-up and production are shown in the Schedule of Materials Control (MCS). Take aggregate quality samples as directed by the Engineer. Sample the following items in accordance with the MCS:

1. Gradation.
2. Coarse Aggregate Angularity
3. Asphalt Content

D.2 Documentation

Include the following production test rests, and mixture on the Department approved Test Summary sheet.

1. Gradation. Sieves listed in 3139.3.B
2. Coarse aggregate angularity
3. Percent asphalt binder content (spot check).
4. Aggregate proportions in use at the time of sampling
5. Tons where sampled
6. Cumulative tons.
7. Tons represented by test
8. Signature Line for Agency and Contractor Representative.
9. MnDOT verification sample test result.

D.3 JMF Limits

The mixture production targets and JMF limits, as shown in Table 2213-1, are listed on the MDR. Field results may deviate from the JMF target; however, JMF limits as show below are used as the specification limits for acceptance.

Table 2213-1 JMF Limits	
Item	JMF Limits
Gradation	Gradation Broadband
Asphalt Binder Content	-0.4%

2363.3 CONSTRUCTION REQUIREMENTS

A. Handling and Placement.

1. **Mixing and Compaction Temperature.** Use binder supplier recommended temperatures. Unless authorized by the Engineer, do not produce the mixture no more than 30°F above the recommended maximum mixing temperature. The Department will not pay for or allow placement of any mixture produced at more than 30°F above the recommended maximum mixing temperature.
2. **Rutting of Existing Surface.** Equipment used to deliver or place the mixture cannot rut the in-place aggregate base (filter) layer or subgrade, or tear or displace the geotextile if used. Any ruts formed must be repaired and leveled to satisfaction of the engineer, at no cost to the agency, prior to placing the mixture so that water draining through the mixture will not pond and create soft spots in the base/subgrade.
3. **PASSRC:**
 - a. **Construction Sequence.**
 - i. Construct interceptor drains (if required by design)
 - ii. Build PASSRC layer
 - iii. Construct pavement.
 - iv. Trench in permeable base drain adjacent to slab.
 - v. Install variable depth 3138 Class 5 shoulder aggregate (do not remove the in-place bituminous shoulders)
 - vi. Place new bituminous shoulder structure.

B. Surface Preparation.

Remove loose or deteriorated surfacing and clean the surface by power sweeping and air blasting. Removal of deteriorated areas from joints, cracks, bituminous patched areas, etc. may require air blasting, the use of a small milling machine, or handwork as directed by the Engineer. Air blasting must be performed with at least 100 psi [690 kPa] equipment.

C. Maintenance.

The contractor is responsible to maintain the integrity of the PASSRC or PASB until the concrete or bituminous pavement is placed on it. Any deficiencies in thickness, smoothness, or density need to be corrected.

1. **Contamination.** Keep the PASSRC and PASB and associated drains free of soils or other contaminants. Contaminated material shall be removed and replaced by the Contractor to the satisfaction of the Engineer at no cost to the Department.
2. **Drainage.** Maintain drainage so water is not allowed to pond in the PASSRC or PASB.
3. **Construction Equipment.** Concrete hauling units, either loaded or empty are permitted on the PASSRC. Only the paver, rollers, and bituminous haul trucks are only allowed to drive on the PASB. The bituminous haul trucks can only drive on the PASB immediately in front of the paver to unload, and then leave the PASB as soon as the bituminous is unloaded.
4. **Density.** PASSRC and PASB need to be dense and stable after construction so it will not rut when the overlying pavement is placed.
5. **Damage.** The contractor will repair the PASB or PASSRC promptly by the Contractor, as directed by the engineer, at no expense to the Agency.

D. Concrete Pavement Construction.

1. **Whitewash Coating.** Within 2 hours prior to constructing a concrete overlay, coat the permeable asphalt layer with a whitewash of hydrated lime and water. A uniform color of whitewash, not darker than the uncoated concrete after curing will be applied to the permeable asphalt layer. The purpose of the whitewash is to reduce the heat generated from the black surface of the permeable asphalt layer, and thus giving an even curing temperature within the pavement. If the whitewash should wear off due to construction operations, replace it or cool the surface with water immediately prior to paving.

2. Dowel Baskets. Use an anchorage system of sufficient length and a minimum shank diameter of 0.177 inch [0.45 cm] to penetrate the in-place concrete a minimum of 1 inch [25 mm]. A minimum of seven anchorage points are required, four on the side of the basket facing the front of the paver. Fasten the baskets to the surface so that they may not be moved vertically or horizontally more than 1/8 inch [3 mm] from the permeable asphalt layer. The anchorage procedure must be demonstrated prior to the start of paving.

E. Drain Installation.

1. Concrete Pavement. Install drain after pavement is constructed
2. Bituminous Pavement. Install drain after the non-wear course(s) are constructed, but before the wearing course is placed.
3. Shoulder/Base Aggregate. Install drains before shoulder/base aggregate is placed.

F. PASB Widening.

1. Subsurface drain. Construct the subsurface drain prior to cutting the pavement widening trench. Place the fine filter aggregate 4 inches [100 mm] above the proposed bottom of the pavement widening. Placement of the subsurface drain after the widening trench has been cut and widening placed will be allowed only with a special widening design and when approved by the Engineer.
2. Trench. Prior to placement of the PASB, shape and compact the bottom of the widening trench. No equipment will be allowed in the trench except that used for compaction. After shaping and compaction of the widening bottom, the exposed edge of the in place pavement must be clean and free of soil so that water is free to drain into the adjacent PASB. Do not crush the in place drain pipe. After compaction, place clean filter aggregate. If the filter aggregate or PASB becomes contaminated, these materials will be replaced or cleaned.
3. Geotextile. If required by the design, upon completion of compaction, place the geotextile in the bottom of the widening trench. Extend the geotextile from the edge of the in place pavement to the inside edge of the drain trench. Do not lap up onto the in-place pavement nor extend across any part of the drain trench.

G. Pavement Density.

1. Method. Use MnDOT 2360.3.D.2, Ordinary Compaction Method
2. Temperature. The contractor is advised that it may be necessary to permit the permeable asphalt layer to cool sufficiently before compaction rolling to prevent rutting and shoving. In no case will compaction be allowed at less than 110°F [43°C].
3. Water. Water may not be used to accelerate the cooling process.
4. Rollers. Self-propelled steel wheeled compacting equipment must weigh at least 8 ton [7.3 tonne]. Rollers must be steel wheeled both front and back and capable of reversing without backlash and equipped with spray attachments for moistening both rollers. Vibratory compaction will **NOT** be allowed. When the mixture placed exceeds 100 tons per hour, at least two rollers must be used. Adequacy of compaction to provide stability will be judged by the Engineer. Over rolling, to the extent that aggregate particles degrade, is not permitted.

H. Verification Testing.

Verification testing will be performed on the Quality Assurance samples for gradation and coarse aggregate angularity. The department will monitor 1 asphalt binder content spotcheck per day. Allowable differences (tolerances) between contractor and MnDOT test results are specified below in Table 2213-3. Substitute the Agency results for acceptance when the tolerance is exceeded.

Item	Allowable Difference
Coarse Aggregate Angularity, % fractured faces (%P)	15
Asphalt binder content:	
Ignition Oven %	0.3
Gradation sieve, % passing:	
No. 4 [4.75 mm] and larger	5
No. 10 [2.00 mm]	3
No. 40 [.425 mm]	3
No. 200 [0.075 mm]	2.0

I Failing Materials

(Gradation, Coarse Aggregate Angularity, and Extracted Asphalt Binder Content)

The determination of price adjustments for failing materials will be based on the specification limits outlined in Table 2213-2 as shown below for that specific test. Reduced payment as shown in the table below will be applied to all tonnage represented by the individual test results that do not meet the limits. The Contractor cannot continue to produce failing mixture. A continual basis is defined as all lots in a day's production failing to meet specification requirements for gradation, crushing, or binder content, or more than 50% of the lots on two or more consecutive days which fail to meet specification requirements for gradation, crushing, or binder content.

Item	Pay Factor, % *
Gradation	95
Coarse aggregate crushing	90
Extracted Asphalt binder content	90
* Apply the lowest pay factor when using multiple reductions on a single test. No price reduction for asphalt content in excess of allowable tolerance provided there is no visual observation of asphalt drain down.	

J. Thickness and Smoothness Requirements.

1. Elevation. The finished surface of permeable asphalt layer at any point of measurement must not vary be more than $\pm 5/8$ inch [16 mm] from the prescribed elevation for that point as determined from the grades staked by the Engineer and the cross section in the Plan.
2. Thickness. Within $\pm 1/4$ inch [6 mm] of the compacted depth shown on the typical section in the plan.
3. Deficient. The contractor will correct any areas which are deficient by more than $1/4$ inch [13 mm] by scarifying, adding mixture, compacting, shaping, and finishing in accordance with these specifications, or directed by the Engineer.
4. Tolerances. Normal specification tolerances apply for bituminous and concrete.

For PASSRC, two alternatives have been developed for control of payment for unbounded concrete overlays. The first option offers Agency surveying; the second option offers Contractor surveying. The designer should insert the selected option in the Special Provisions. The 2 options are listed below as Option #1 and Option #2. If the designer does not say which option to use leave both in.

Option #1 - Agency Survey Method for Pavement Profile Control

1. Place the PASSRC layer to the width and compacted depth shown on the typical section in the plans.
2. After placement of all the PASSRC, the Contractor will notify the Agency that the Agency has 5* days to survey the pavement surface at 100 foot [30 m] intervals (25 feet [7 m] in transition areas)

- on centerline and 12 feet [3.6 m] left and right of centerline and place hubs at 50 foot intervals on both sides of roadway. Based on this survey, the Agency will establish a concrete paving profile that closely follows the old profile to control concrete quantity but has not abrupt changes.
3. Use a stringline for grade control on both sides of the roadway during paving.
 4. The Contractor will be paid for all of the Structural Concrete produced and placed up to 102 percent of the amount computed by the agency survey crew in their determination of the profile and resulting estimated structural concrete quantity, unless otherwise approved by the Engineer. Determine the quantity by computerized printouts from the Contractor's plant as verified by cement cutoffs with the consideration of any waste as determined by the Engineer.
 5. The Contractor cannot make a claim for any additional ride incentive or reduction in the ride disincentive due to the agency selecting the finished profile or the concrete overlay.
 6. Take concrete cores 2 feet [0.6 m] from the outside pavement edge.

* Suggested time period. This may be modified by the Agency.

Option #2 - Contractor Survey Method for Pavement Profile Control

1. Place the PASSRC layer to the width and compacted depth shown on the typical section in the plans.
2. After placement of all the PASSRC, the Contractor will survey the pavement surface at 100 foot [30 m] intervals (25 feet [7 m] in transition areas) on centerline and 12 feet [3.6 m] left and right of centerline and place hubs at 50 foot intervals on both sides of roadway. Based on this survey, the Contractor will use these results to establish a recommended paving profile for review by the Engineer. The Engineer will approve or disapprove the Contractor's recommended paving profile within 3 working days. Approval is based on establishing a concrete paving profile that closely follows the old profile to control concrete quantity but has no abrupt changes.
3. Use a stringline for grade control on both sides of the roadway during paving.
4. The Contractor will be paid for all of the Structural Concrete produced and placed up to 102 percent of the amount computed by the Contractor's survey crew in their determination of the profile and resulting estimated structural concrete quantity, unless otherwise approved by the Engineer. Determine the quantity by computerized printouts from the Contractor's plant as verified by cement cutoffs with the consideration of any waste as determined by the Engineer.
5. The Contractor cannot make a claim for any additional ride incentive or reduction in the ride disincentive due to the agency selecting the finished profile or the concrete overlay.
6. Take concrete cores 2 feet [0.6 m] from the outside pavement edge.

2363.4 METHOD OF MEASUREMENT

Measurement for PASB and PASSRC will be in accordance with the following. Bituminous mixture and bituminous material for mixture will be paid for separately.

Measurement will be made by the weight of bituminous mixture for the permeable asphalt layer. Payment will be made at the Contract bid price per ton [metric ton]. Payment for the accepted bituminous mixture will be payment in full for all costs of constructing the permeable asphalt layer, including the costs of mixture production, aggregate incorporation, placement, and compaction. Cost for Bituminous material is specifically excluded. Measurement will be made by the weight of bituminous material incorporated into the permeable asphalt layer. Payment will be made at the Contract bid price per ton [metric ton]. Payment for Bituminous material, based on the acceptance of the permeable asphalt layer, will be payment in full for bituminous material, any additives, and the incorporation of the bituminous material into the mixture.

2363.5 BASIS OF PAYMENT

Payment for the accepted quantity of permeable asphalt layer at the Contract unit price of measure will be compensation in full for all costs of furnishing and applying all materials required in this specification. The unit price includes all labor materials, and equipment necessary to complete the work.

Payment for geotextile, when required for widening designs, will be considered incidental.

Item No.	Item	Unit
2363.509	Bituminous Mixture for Permeable Asphalt Stabilized Stress Relief Course	ton [metric ton]
2363.509	Bituminous Mixture for Permeable Asphalt Stabilized Base	ton [metric ton]
2363.509	Bituminous Material for Mixture	ton [metric ton]

2365 STONE MATRIX ASPHALT -- SMA

2365.1 DESCRIPTION

This work consists of constructing a Stone Matrix Asphalt Wearing Course Mixture (SMA) placed on a prepared surface in accordance with these specifications.

Construct the SMA to the lines, grades, thicknesses, and typical cross-sections shown on the plans or established by the Engineer.

Stone Matrix Asphalt Mixture Designation Code: **SMWEE640E**

2365.2 MATERIALS

A Aggregates

Use only virgin aggregates.

A.1 Aggregate Requirements

Provide mineral aggregate meeting the requirements of Table 2365-1, "Stone Matrix Asphalt Aggregate Gradation Broad Bands" and Table 2365-2, "Stone Matrix Asphalt Mixture Aggregate Requirements":

Table 2365-1	
Stone Matrix Asphalt Aggregate Gradation Broad Bands	
(% passing of total washed gradation)	
Sieve Size, inch (mm)	% Passing
¾" (19.0)	100
½" (12.5)	86-96
3/8" (9.5)	60-85
#4 (4.75)	25-35
#8 (2.36)	15-25
#200 (0.075)	8.0-12.0

Table 2365-2 Stone Matrix Asphalt Mixture Aggregate Requirements	
Aggregate Blend Property	Requirements
Coarse Aggregate Angularity (MnDOT 1214) (one face/two face), % wear	100/90
Fine Aggregate Angularity	Use manufactured sand
Coarse Aggregate Absorption, % (MnDOT 1204)	≤ 2
Voids in Coarse Aggregate (VCA_{DRC}) (MnDOT 1211 & AASHTO T19)	VCA _{mix} < VCA _{DRC}
Flat and Elongated Particles, max % by weight, (MnDOT 1208)	10 (3:1 ratio)
Clay Content (MnDOT 1215)	45
Total Spall in fraction retained on the #4 [4.75mm] sieve (MnDOT 1209)	1.0
Maximum Spall Content in Total Sample (MnDOT 1209)	1.0
Maximum Percent Lumps in fraction retained on the #4 [4.75mm] sieve	0.5
Class B Carbonate Restrictions	
Maximum% -#4 [-4.75mm]	50
Maximum% +#4 [-4.75mm]	0

A.2 Los Angeles Ratter

The Los Angeles Rattler loss on the coarse aggregate fraction (material retained on the #4 sieve [4.75-mm] cannot exceed 35 percent for any individual source used within the mix (MnDOT 1210).

A.3 Magnesium Sulfate loss on coarse aggregate fraction for each source.....3139 C

A.4 Mineral Filler AASHTO..... M17

B Additives

An additive is any material added to an asphalt mixture or material, such as mineral filler, asphalt additives, anti-strip, stabilizers, and similar products that do not have a specific pay item. When the Contract requires additives, compensation is included with the pay items for the appropriate mixture. If directed to incorporate additives, the compensation will be as Extra Work, at the unit price specified in the proposal. No compensation will be made for additives incorporated at the Contractor's option.

Do not incorporate additives into the mixture without approval of the Engineer. Add anti-foaming agents to asphalt cement at the manufacturer's recommended dosage rate.

C SMA Asphalt Stabilizer AASHTO 305

Use a cellulose fiber asphalt stabilizer additive to control drain-down in the SMA mixture. Feed the stabilizing additive through a separate system that proportions the required amount of stabilizer in uniform distribution at a dosage rate within 0.2-0.4 percent by weight of the total mix. The system must have low-level and no-flow indicators and a printout of the feed rate in lbs/min. Additionally, the stabilizer supply line must include a section of transparent pipe for observing consistency of flow or feed.

D Asphalt Binder Material 3151

Use PG 70-28, meeting the requirements of AASHTO MP 19-10.

E Mixture Design

E.1 General Design

Design the mixture in conformance with AASHTO R 46-08, Standard Practice for Designing Stone Matrix Asphalt. Additional information on SMA mix design is found in Appendix B of the National Asphalt Pavement Association information Series 122, Designing and Constructing SMA Mixtures State-of-the-Practice.

Use MnDOT Laboratory Manual Method 1816 (Corelok) to determine mixture bulk specific gravity.

E.2 Aggregate

At least 15 calendar days before beginning production, submit to the District Materials Laboratory a minimum of 80 lbs (35kg) for aggregate quality testing.

At least 30 calendar days prior to production, submit to the District Materials Laboratory 80 lbs (35kg) of each aggregate that require magnesium sulfate soundness testing.

At least 7 working days prior to the start of asphalt production, submit a minimum of 150 lbs. [60kg] of the coarse aggregate fraction from the selected design blend (JMF). This fraction will be tested for the voids in coarse aggregate (VCA_{drc}) (MnDOT 1211 & AASHTO T19).

E.3 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 2365-1, "Stone Matrix Asphalt Mixture Aggregate Gradation Broadband", Table 2365-2, "Stone Matrix Asphalt Mixture Aggregate Requirements" and Table 2365-5, "Stone Matrix Asphalt Mixture Requirements". Use forms approved by the Department for the submission. Submit the design as a Laboratory Mix Design (Option 1).

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 2365-3 Stone Mastic Asphalt Mixture Sample Requirements	
Item	Gyratory Design
Uncompacted mixture sample size	75 lb [30 kg]
Number of compacted briquettes	2
Coarse Aggregate Fraction	150 lb (60kg)

C.1 Tensile Strength Ratio

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, re-submit a new mix design as described above. The Contractor may use one of the following options to verify that the TSR meets the requirements in Table 2365-5, "Stone Matrix Asphalt Mixture Requirements".

C.1.a 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 minutes at 290 °F [144 °C] cure time for both groups and follow procedures Laboratory Manual Method 1813.

C.1.b Option B

Batch and cure in accordance with Option A. Compact, and submit briquettes and uncompacted mixture in accordance with Table 2365-4, "Option B Mixture Requirements".

Table 2365-4	
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	5.5 % – 6.5 %
* 6 in [150 mm] specimens.	

For both options, cure for 2 h ±15 min at 290° F [144° C] meeting the requirements in the MnDOT Laboratory Manual Method 1813.

D Mixture Requirements

The Department will base initial mixture evaluation on the trial mix tests in accordance with Table 2365-5, “Stone Matrix Asphalt Mixture Requirements” and Table 2365-6, “Stone Matrix Asphalt Minimum Asphalt Content”.

Table 2365-5	
Stone Matrix Asphalt Mixture Requirements	
Gyrations for N_{design}	75
Air Voids, % -- Wear	4.0%
Fines/Effective Asphalt	1.2-2.0
Tensile Strength Ratio, min%	70
VMA, %	17.0
VFA, % -- Wear	70-80
Draindown - based on a 1 hour reading at the anticipated production temperature	≤ 0.3 %
Stabilizer by weight of total mix, %	0.2 – 0.4
VCA Ratio	$VCA_{MIX} < VCA_{DRC}$
Minimum Asphalt Requirement, % by weight of mix	See Table 2365-6

D.1 Minimum Asphalt Content

Asphalt content is established based on the combined aggregate bulk specific gravity, Gsb. Use Table 2365-6, “Stone Matrix Asphalt Minimum Asphalt Content” to determine the minimum asphalt content.

Table 2365-6	
Stone Matrix Asphalt Minimum Asphalt Content	
Combined Aggregate Bulk Specific Gravity	Minimum Asphalt Content, Percent
<2.400	6.8
2.401-2.450	6.7
2.451-2.500	6.6
2.501-2.550	6.5
2.551-2.600	6.3
2.601-2.650	6.2
2.651-2.700	6.1
2.701-2.750	6.0
2.751-2.800	5.9
2.801-2.850	5.8
2.851-2.900	5.7
2.901-2.950	5.6
2.951-3.000	5.5

D.2 Documentation

Include the following documentation and test results for 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) The following temperature ranges as supplied by the asphalt binder supplier:
 - (3.1) Laboratory mixing and compaction,
 - (3.2) Plant discharge, and
 - (3.3) Field compaction.
- (4) 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 for each aggregate to be incorporated into the mixture.
- (5) Source descriptions of the following:
 - (5.1) Location of material,
 - (5.2) Description of materials,
 - (5.3) Aggregate pit or quarry number, and
 - (5.4) Proportion amount of each material in the mixture in percent of total aggregate.
- (6) Composite gradation based on (4) and (5) above.
- (7) 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. Use MnDOT 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.
- (8) Test results from the composite aggregate blend at the proposed JMF proportions showing compliance with Table 2365-2, "Stone Matrix Asphalt Mixture Aggregate Requirements":
 - (8.1) Coarse Aggregate Angularity,
 - (8.2) For the trial blend(s), determine the unit weight of aggregates (lb/ft³), voids in the Coarse Aggregate-Dry Rodded Condition (VCADRC) according to AASHTO T19. The VCA ratio (VCAmix/VCADRC) shall be less than 1.0, i.e. VCAmix < VCADRC.
 - (8.3) Flat and Elongated determined at 3:1 ratio
- (9) Asphalt binder percentage in units of 0.1 percent based on the total mass of the mixture and the PG grade.
- (10) Each trial mixture design includes the following:
 - (10.1) Using the selected design gradation, prepare mixes at the three binder contents in increments of 0.5 percent with at least one point above and one point below the optimum asphalt binder percentage.
 - (10.2) Conduct draindown test (AASHTO T305) on loose mix at a temperature 27°F (15°C) (15°C) higher than anticipated production temperature.
 - (10.3) 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.
 - (10.4) Test results on at least two specimens at each asphalt binder content for the individual and average bulk specific gravities, density, and heights.
 - (10.5) Percent air voids of the mixture at each asphalt binder content.
 - (10.6) VMA for each asphalt binder content.
 - (10.7) Fines to Effective Asphalt (F/A) ratio calculated to the nearest 0.1 percent.
 - (10.8) Evidence that the completed mixture will conform to the specified VCA ratio of less than 1.0.
- (11) Percent and manufacturer's data for type of stabilizer used.

D.3 Mixture Design Report

The Department will issue an initial Mixture Design Report (MDR) consisting of the JMF after review of the submitted design. The review will include the Department's test results submitted aggregate and mixture. A preliminary MDR will provide the JMF limits to begin production of a test strip.

D.4 Initial SMA Test Strip Verification

Do not begin full-scale production of the SMA mixture until it is shown, in a test strip, that the mixture can be produced, placed, and compacted to the requirements of this specification. Limit the test strip to 500 tons with a minimum requirement of 200 tons placed at the specified thickness and width indicated in the contract. During construction of the test strip take a minimum of 2 mixture samples to determine mixture properties as shown in the

Production Start-Up Testing Rate table shown above. Take one sample within the first 100 tons of mixture produced and the other randomly within the remaining mixture produced. After both samples are obtained cease production of the SMA until mixture properties are tested and evaluated by both the Contractor and the Department. Resume production when:

- 1) The Contractor's and the Department's test results are within the allowable testing tolerances shown in Table 2365-7, and
- 2) Each of the Contractor's test results are within the JMF limits as indicated on the Mixture Design Report, and
- 3) The average of the two Contractor test results meets the requirements shown in the table for SMA mixture requirements, and
- 4) The average of two cores from the roadway meets the minimum density requirement as specified in this provision. One core shall be taken at random in the area representative of where the first mixture sample was obtained. The other core shall be taken at random in the area representative of the second mixture sample.

If the material in the test strip does not meet the requirements listed above another test strip will be required. With the approval of the Engineer, the test strip may be placed within the project limits. A final MDR will be issued once the test strip meets specification requirements.

E Mixture Quality Management

E.1 Quality Control

Perform Quality Control (QC) as part of the production process. QC is the process control of the operations related to mixture production and determining the quality of the mixture being produced. The QC sample is the Contractor's sample taken and tested during production and used to control the production process. Provide and maintain a QC program for stone matrix asphalt pavement production, including mix design, process control inspection, sampling and testing, and adjustments in the process related to the production of the stone matrix asphalt pavement.

E.2 Plant 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 sections 1200, 1800, and 2000 of the Mn/DOT Laboratory Manual.
- (4) A Department-signed Mixture Design Report (MDR) before mixture production.

E.3 Quality Assurance

The Engineer will perform Quality Assurance (QA) as part of the acceptance process. QA is the process of monitoring and evaluating various aspects of the Contractor's testing as described below. The QA sample is the Department's companion sample to the Contractor's QC sample. QA testing is performed 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.

E.4 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 MnDOT uses. Take all verification samples from the truck box at the plant site. 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.

Perform verification testing on at least one set of production tests daily to verify the requirements of Table 2365-1, "Stone Matrix Aggregate Gradation Broad Bands", Table 2365-2, "Stone Matrix Asphalt Pavement Mixture Aggregate Requirements", and Table 2365-5, "Stone Matrix Asphalt Mixture Requirements". Compare the verification companion sample to the verification sample for compliance with allowable tolerances in Table 2365-7. The Department will consider the verification process complete if the Contractor's verification companion meets the tolerances in Table 2365-7.

If the tolerances between the Contractor's verification companion and the Department's verification sample do not meet the requirements of Table 2365-7, 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.

Table 2365-7	
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
VMA	1.2
Coarse Aggregate Angularity, % fractured faces (%P)	15
<u>Asphalt binder content:</u>	
Ignition Oven %	0.3
<u>Gradation sieve, % passing:</u>	
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]	4
No. 200 [0.075 mm]	2.0

E Contractor Quality Control

Provide QC technicians certified as a Level I Bituminous Quality Management (QM) Tester meeting the requirements of the MnDOT 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.

F Sampling and Testing

Take QC/QA samples from the truck box at the plant site. Sample randomly and in accordance with the Schedule of Materials Control and this provision. QC/QA samples are to be quartered from a larger sample of mixture. The procedure for truck box sampling is on the Bituminous Office website. Store compacted QC mixture specimens and loose QC and Department's QA mixture 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 Start-Up and Production Test Rates

G.1 Start –Up Testing Rates

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

Table 2365-8 Stone Matrix Asphalt Production Start-Up Testing Rates		
Production Test	Testing Rates	Lab Manual Method
Bulk Specific Gravity	1 test per 500 tons (450 metric tons)	MnDOT 1816 (Corelok)
Maximum Specific Gravity	1 test per 500 tons (450 metric tons)	MnDOT 1807
Air Voids (calculated)	1 test per 500 tons (450 metric tons)	MnDOT 1808
Asphalt Content	1 test per 500 tons (450 metric tons)	MnDOT 1852 & 1853
VMA (Calculated)	1 test per 500 tons (450 metric tons)	AASHTO R46 & SP 2
Gradation	1 test per 500 tons (450 metric tons)	MnDOT 1203
Fines to Effective AC (calculation)	1 test per 500 tons (450 metric tons)	
Fine Aggregate Angularity*		MnDOT 1206
Coarse Aggregate Angularity	1 test per 1000 tons (900 metric tons)	MnDOT 1214
VCA Ratio (calculation)	1 test per 500 tons (450 metric tons)	AASHTO R46 & T19
Draindown	1 test per 500 tons (450 metric tons)	AASHTO T305

* No FAA requirement, however, fine aggregate shall be 100% crushed.

G.2 Production Test Rates

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

Table 2365-9 Stone Matrix Asphalt Production Testing Rates		
Production Test	Sampling/Testing Rates	Lab Manual Method
Bulk Specific Gravity	1 test per 1000 tons (900 metric tons)	MnDOT 1816 (Corelok)
Maximum Specific Gravity	1 test per 1000 tons (900 metric tons)	MnDOT 1807
Air Voids (calculated)	1 test per 1000 tons (900 metric tons)	MnDOT 1808
Asphalt Content	1 test per 1000 tons (900 metric tons)	MnDOT 1852 & 1853
VMA (calculated)	1 test per 1000 tons (900 metric tons)	AASHTO R46 & SP 2
Gradation	1 test per 1000 tons (900 metric tons)	MnDOT 1203
Fines to Effective AC (calculated)	1 test per 1000 tons (900 metric tons)	AASHTO R46 & SP 2
Coarse Aggregate Angularity	2 tests/day for a minimum of 2 days, then 1 per day if CAA is met. If CAA >8% of requirement, 1 sample/day but test 1/week.	MnDOT 1214
Fine Aggregate Angularity (FAA)*		MnDOT 1206
TSR	As directed by the Engineer	MnDOT 1813
Aggregate SpG & Absorption	As directed by the Engineer	MnDOT 1204, 1205
Mixture Moisture Content	As directed by Engineer	MnDOT 1855
Asphalt Binder	Sample 1 st load then 1 per 250,000 gal (1,000,000 liter) -sample size 1 qt.	MnDOT 5-693.920
Draindown	1 test per day	AASHTO T305
VCA Ratio (calculated)	1 test per 1000 tons (900 metric tons)	AASHTO R46

* No FAA requirement, however, fine aggregate shall be 100% crushed.

H Documentation:

Maintain documentation, including test summary sheets and control charts, on an ongoing basis. 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.

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 2365-1, "Stone Matrix Asphalt Pavement Aggregate Gradation Broad Bands".
- (2) Coarse aggregate crushing (1 & 2 face),
- (3) Maximum specific gravity ($G_{mm.}$),
- (4) Bulk specific gravity (G_{mb}),
- (5) Percent total asphalt binder content.
- (6) Calculated production air voids (V_a),
- (7) Aggregate proportions in use at the time of sampling,
- (8) Individual aggregate G_{sb} (both minus #4 and combined),
- (9) Tons where sampled,
- (10) Tons represented by a test and cumulative tons produced,
- (11) Signature Line for MnDOT and Contractor Representative,
- (12) Mixture Moisture Content, and
- (13) MnDOT verification sample test result.
- (14) VCA ratio

- (15) Drain-down value in percent
- (16) VMA
- (17) Fines to effective asphalt ratio (F/E)
- (18) Amount of stabilizer

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 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.

Furnish an electronic printout (long form recordation) from an automated plant blending control system at 20 minute intervals when the plant is producing mixture. The Engineer may waive this requirement if the plant does not have the capability to produce the automated blending control information; however, the Contractor must then perform daily spotchecks to determine percent new asphalt added.

Include the following information on the plant control printout for Drum Plants:

- (1) Both the virgin and recycle belt feed rates (tons/hr),
- (2) Feeder bin proportions (%),
- (3) Total % asphalt cement in the mixture,
- (4) Virgin asphalt cement added (%)
- (5) Mixture Temperature °F [°C],
- (6) Mixture code,
- (7) Date and time stamp, and
- (8) Current tons of mixture produced and daily cumulative tons of mixture produced at time of printout.

Provide a daily electronic printout of the plant calibration (SPAN) numbers for each bin and meter.

I JMF Limits

Table 2365-10 Stone Matrix Asphalt JMF Limits (N=4)	
Item	JMF Limits
Production air voids, %	±1.0
Asphalt Binder Content, Percent	±0.4
VMA	-0.3
Sieve - % Passing	
3/4" [19mm], 1/2" [12.5mm], 3/8" [9.5 mm]	± 4
No. 4 [4.75], No. 8 [2.36 mm]	± 3
No. 200 [0.075 mm]	± 2.0

The mixture production targets and JMF limits are listed on the Mixture Design Report. JMF limits are used as the criteria for acceptance of materials based on individual (single) test results. Gradation JMF limits are not allowed outside the broadband requirements in Table 2365-1, "Stone Matrix Asphalt Aggregate Gradation Broad Bands".

I.1 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.

I.2 JMF Bands

JMF Bands are the area between the target, as identified on the Mixture Design Report, and the JMF limits.

J 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 2365-10, "Stone Matrix Asphalt JMF Limits" for gradation, asphalt content, and aggregate proportions meeting the requirements of the reviewed Mixture Design Report. Use all aggregate proportions meeting the requirements of the Mixture Design Report unless the aggregate proportion is 0 percent.

K JMF Request for Adjustment

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 Department 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 2365-1, "Stone Matrix Asphalt Pavement Aggregate Gradation Broad Bands", Table 2365-2, "Stone Matrix Asphalt Pavement Mixture Aggregate Requirements", and Table 2365-5, "Stone Matrix Asphalt Pavement Mixture Requirements," the Department will issue a revised Mixture Design Report.

Use an interactive communication process with the Engineer before making JMF adjustments. Make JMF adjustments only within the mixture specification gradation design broadbands in accordance with Table 2365-1, "Stone Matrix Asphalt Pavement Aggregate Gradation Broad Bands". Submit a new JMF if redesigning the mixture.

The department will not allow consecutive requests for a JMF adjustment without production data.

L Failing Materials – Gradation, Coarse Aggregate Angularity, Air Voids, VMA, and Percent Asphalt Binder

Material acceptance is based on individual and moving average test results. Use isolated test results for acceptance of air voids and VMA 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 exceeding the JMF limits.

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 2365-8, "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 2365.2.G.14.d, "Moving Average Failure at Mixture Start-Up – Production Air Voids," 2365.2.G.14.e, "Moving Average Failure at Mixture Start-Up — Adjusted AFT," 2365.2.G.14.f, "Moving Average Failure - Production Air Voids," and 2365.2.G.14.g, "Moving Average Failure — Percent Asphalt Binder Content, Gradation, and Adj. AFT."

L.1 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 2365-16, “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 less 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.

L.2 Individual Failure – Gradation, Percent Asphalt Binder, Production Air Voids, and VMA

Table 2365-11	
Reduced Payment Schedule for Individual Test Results	
Item	Pay Factor, % *
Gradation	95
VMA	85
Coarse aggregate crushing	90
Asphalt binder content	90
Production air voids, individual and isolated †	80
* Apply the lowest pay factor 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.	

L.3 Individual Failure at Mixture Start-Up– VMA

At the start-up of mixture production, before a moving average of four can be established, the first three (3) individual test results for VMA will be used for acceptance. After 4 samples have been tested and a moving average of four can be established, acceptance will be based on individual and moving average VMA.

If, at the start of production, any of the first three (3) individual VMA test results exceeds twice the JMF bands from the target listed on the Mixture Design Report, the material is considered unsatisfactory or unacceptable. Reduced payment as outlined in Table 2365-11 shall apply to all tonnage placed from the sample point of the failing test until the sample point when the test results are back within twice the JMF limits. When the failure occurs at the first test, after the start of production, the tonnage subjected to reduce payment shall be calculated as described above and shall include the tonnage from the start of production.

L.4 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.

L.5 Moving Average Failure at Mixture Start-Up – VMA

When a moving average failure occurs within any of the first 3 moving average results after mixture start-up (tests 4, 5, 6), the mixture will be considered acceptable if the individual VMA, corresponding to the moving average failure is within the JMF limits. If the individual VMA is not within the JMF limit, the mixture will be considered unacceptable and the Engineer will decide whether the mixture is subject to removal and replacement or reduced payment. If the mixture is to be removed and replaced, the Contractor at his expense will perform the work. Reduced payment will be 75 percent of the Contract bid price. Tonnage subjected to replacement or reduced payment shall be calculated as the tons placed from the sample point of the failing moving average result and corresponding individual VMA beyond the JMF limit to the sampling point when the individual test result is back within the JMF limit.

L.6 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 2365-12	
Reduced Payment Schedule for Moving Average Test Results	
Item	Pay Factor, % *
Gradation	90
Coarse and fine aggregate crushing	NA (individual failures only)
VMA	80
Asphalt binder content	80
Production air voids	70

* Lowest Pay Factor applies when there are multiple reductions on a single test. test result is back within the JMF limit.

L.7 Moving Average Failure – Percent Asphalt Binder Content, VMA, and Gradation

For mixture properties including asphalt binder content, VMA, and gradation, where the moving average of four exceeds the JMF limits, the mixture is considered unacceptable and the Engineer will decide whether the mixture is subject to removal and replacement or reduced payment. If the mixture is to be removed and replaced, the Contractor at his expense will perform the work. Reduced payment, percent of the Contract bid price, is shown in Table 2365-12. Tonnage subjected to replacement or reduced payment is calculated 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. When the failure occurs at the first test after the start of daily production, tonnage subjected to reduced payment shall include the tonnage from the start of production that day.

L.8 Coarse Aggregate Crushing Failure

If any CAA test results do not meet the requirements specified in Table 2365-1, the Department may reduce payment for the placed material in accordance with Table 2365-11, "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.

2365.3 CONSTRUCTION REQUIREMENTS

A Restrictions

A.1 Asphalt Release Agents

Do not use petroleum distillates to prevent adhesion of asphalt mixtures to equipment. An asphalt release agent must meet the criteria for "Effect on Asphalt" as described in the most recent Asphalt Release Agent on file in MnDOT's Office of Environmental Services. Drain excess release agents from tuck boxes prior to loading.

A.2 Edge Drop Off

When construction is under traffic, the requirements of 2221.3.D will apply.

A.3 Surge and Storage Bins

Store the asphalt mixture for no more than 1 h at storage facilities that prevent segregation of the mix and drainage of asphalt from the mix. Maintain the mixture at 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 SMA when weather or roadbed conditions or moisture conditions of the roadway surface are judged unfavorable by the Engineer.

Place SMA mixtures only when the ambient air temperatures are at least 10C (50F).

A.5 Mixing and Discharge of Materials

Notify the Engineer of the recommended mixing temperatures as provided from the asphalt supplier. Unless authorized by the Engineer, do not produce the mixture no more than 30°F above the recommended maximum mixing temperature. Use the automated plant control printout to monitor discharge temperature. The Department will not pay for or allow placement of any mixture produced at more than 30°F above the recommended maximum mixing temperature.

A.6 Asphalt Binder Sampling Valve

Obtain asphalt binder samples from a sampling valve located between the pump and the drum. Sample each type of asphalt binder used in mixture production after 50 tons of mixture has been produced, then sample at a rate of one per 250,000 gal [1,000,000 L]. A minimum of 1 gallon of binder must be drawn and wasted from the sampling valve before the actual sample is drawn. 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 Central Materials Laboratory. Contact the Department Chemical Laboratory Director for disposition of failing asphalt binder samples.

B 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.

C Tack Coat

Apply a uniform asphalt tack coat to the clean and dry existing asphalt or concrete surface and to the surface of each course or lift constructed, except for the final course or lift, in accordance with 2357. Coat the contact surfaces of all fixed structures and the edge of the in-place mixture in all courses at transverse joints and in the wearing course at longitudinal joints. Do not coat the longitudinal joint if a rubberized asphalt joint adhesive will be applied to the vertical face of the joint. A uniform application will not have streaks (corn rows), bare spots, puddles, or other irregular patterns. Allow emulsified asphalt tack coats to break, as indicated by a color change from brown to black, before placing subsequent lifts. Take tack samples from the asphalt distributor according to rates provided in the Material Control Schedule. The Inspector will monitor the sampling the Contractor performs.

D Rollers

D1 Steel-Wheeled Rollers

Use self-propelled steel wheeled compacting equipment must weigh at least 8 ton [7.3 tonne]. Steel-wheel rollers in the vibratory mode are only allowed when approved by the Engineer.

D2 Pneumatic Tired Rollers

Self-propelled pneumatic tired compacting equipment is only allowed when approved by the Engineer.

E Compaction

After spreading each course, compact in accordance with the maximum density method as described below, unless the ordinary compaction method is otherwise specified in the special provisions. Do not allow rollers to stand on the uncompacted mixture or newly rolled pavement with a surface temperature greater than 140 °F [60 °C].

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.

E.1 Maximum Density

Compact the pavement to at least the minimum required maximum density values in accordance with Table 2365-13, "Required Minimum SMA Lot Density."

Table 2365-13 Required Minimum SMA Lot Density	
All SMA Mixtures	
% Gmm	93.0

E.1.a Density Determination (Core Bulk Density)

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. Use Laboratory Test Method 1816, Corelok, to determine core density.

E.1.b 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 between 6 h and 8 h after mixture placement. Do not reroll compacted mixtures with deficient densities.

E.1.c Stop Production

If all the lots in a day's production or greater than 50 percent of the lots on multiple days fail to meet the minimum density requirement stop production and determine the source of the problem. Discuss with the Engineer what corrective action will be taken to bring the work into compliance with specified minimum required density.

E.1.d Lot Determination

Table 2365-14 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 tons [820 tonne] or part thereof.	

E.1.e 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.

E.1.f 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 taking care to prevent damage to them. Schedule the approximate time of testing during normal project work hours to allow the Engineer to observe the test and to record the corelok testing 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.

E.1.g Companion Core Testing

The Department will select at least one of the two companion cores per lot to test for verification.

E.1.h Tolerance Comparison

E.1.h(1) Tolerance Comparison – Individual

Compare the individual core bulk specific gravities obtained by the Contractor and by the Department. If the bulk specific gravity between the Contractor and the Department cores differ by more than 0.030, use the Department's bulk specific gravity.

E.1.h(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.

E.1.i Recoring

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.

E.1.j Payment Schedule

Determine payment for density in accordance with Table 2365-15.

Percent of Maximum Specific Gravity	Percent Payment
Above 97.0	98
93.0 –97.0	100
91.0 – 92.9	98
89.0-90.9	95
Less than 89.0	remove and replace

F 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:

Course/Location	Description	Tolerance
Wear	Tolerance of final 2 lifts from the edge of a 10 foot [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 foot [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 inches [75 mm] greater than the plan distance. The edge alignment of the wearing lift on tangent sections and on curve sections of 3 degrees or less can't deviate from the established alignment by more than 1 inch [25 mm] in any 25 foot [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 1/4" [6mm] than the concrete surface.	See Description
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 not to exceed 1/4" [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
Finished Surface	No flushing or "fat" spots	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.

In addition to the list the above the pavement surface must meet requirements of 2399 (Pavement Surface Smoothness) requirements.

F.1 Lift Thickness

After compaction, the thickness of the SMA will be within a tolerance of ¼ in [6 mm] of the thickness shown on the plans. The Engineer may require removal and replacement of any part of any lift that is constructed to less than the minimum required thickness, 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 exceed 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 or at the discretion of the Engineer and at the Contractor's expense may be required to be removed and replaced.

2365.4 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.

2363.5 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, and asphalt stabilizer.

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 1403, "Extra Work."

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 Table 2365-16, "Surface Requirements" and surface smoothness requirements in accordance with 2399 for occasional variations and not for continuous over-running or under-running, unless otherwise required by the Engineer.

The Department will pay for plant mixed SMA on the basis of the following schedule:

Item No.:	Item:	Unit:
2365.501	Type SM* Wearing Course Mixture †‡	ton [metric ton]
*	Aggregate size Designation 12.5	
†	Traffic level 6	
‡	AC binder grade designation "H"	

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 Mean Roughness Index (MRI) value per 0.1 mi [0.16 km] segment. The Department defines “Areas of Localized Roughness” (ALR) as areas greater than or equal to the limiting criteria for a continuous MRI 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 MnDOT Pavement Engineering Section. Refer to the procedures maintained by the MnDOT Pavement Engineering Section or to the MnDOT 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-B-E.ERD standardized format in accordance with Table 2399-1:

Table 2399-1 Standardized Naming Convention for ERD Files	
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)
B	Beginning station
E	End station

B Profile Analysis Software

Use ProVAL software to conduct a profile analysis to determine Smoothness and ALR. 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 MnDOT 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 both IP and the operator certification.

D.2 Day of Profiling

Submit a printout containing the IP's settings, each segment's left and right International Roughness Index (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 "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 ALR, 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 ALR, 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 ALR 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 "Smoothness Assurance" analyses to the Engineer. Submit a spreadsheet summary in tabular form, with each 0.1 mi [0.16 km] segment occupying a row to the Engineer. The Contractor may access an acceptable spreadsheet summary template in electronic form on the MnDOT Smoothness website.

2399.3 CONSTRUCTION REQUIREMENTS

Using an IP, measure the final pavement surface for MRI unless otherwise excluded in Table 2399-3.

Unless otherwise approved by the Engineer, perform all profiling in the presence of the Engineer. Schedule profiling with the Engineer. Reprofile any pavement profiled in the absence of the Engineer as directed by the Engineer at no additional cost to 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 [0.16 km] in length. Evaluate the remainder segment less than 0.1 mi [0.16 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 Smoothness before the beginning of construction and after the completion of construction. Use the same stationing for the final profiling as the stationing used for the initial profiling to allow for a direct comparison of Smoothness when calculating the percent improvement. Measure the Smoothness Before Paving and the Smoothness After Paving values with the same IP.

The Engineer will use a 10 ft [3.05 m] straightedge to measure for surface deviations greater than ¼ in [6.35 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 ALR 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 and loops	
Acceleration and deceleration lanes less than or equal to 1,000 ft [304.80 m] in length	
Projects less than 1,000 ft [304.80 m] in length	
Bridge decks and approach – the occurrence of bridges shall not interrupt the continuity determination	
For Bituminous Pavements	
Single lift overlays over concrete	
For Concrete Pavements	
Intersections constructed under traffic – begin and end exclusion 100 ft [30.48 m] from the intersection radius	

Table 2399-3 Areas Excluded from Smoothness and ALR Evaluation	
For All Pavements	
Paving in areas with a posted vehicle speed less than 30 mph [48 km/hr]	
Turn lanes, crossovers	
10 ft [3.05 m] on either side of obstructions in lane that obstruction is located	
Side streets, side connections	
150 ft [45.72 m] before intersections that end at a stop sign or yield signs at a roundabout	
For Bituminous Pavements	
Paved shoulders	
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	
For Concrete Pavements	
Undoweled shoulders less than or equal to 10 ft [3.05 m] in width	
Headers adjacent to colored concrete	

C Calculations

C.1 Smoothness

Obtain the Smoothness values in an individual lane using the ProVAL "Smoothness Assurance" analysis with the 250 mm filter.

For percent improvement projects, use the Smoothness Before Paving and Smoothness After Paving values to calculate the percent ride improvement.

C.2 Areas of Localized Roughness

Identify ALR using the ProVAL "Smoothness Assurance" analysis, calculating MRI with a continuous short interval of 25 ft [7.62 m] with the 250 mm filter.

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 Smoothness 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 [30.48 m] in length and 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 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 [0.16 km] segment after performing corrective work as directed by the Engineer and enter the reprofiled Smoothness values into the final spreadsheet summary.

D.1.a Bituminous Pavements

Table 2399-4 contains pay adjustments for bituminous pavements. See Section 2360, "Plant Mixed Asphalt Pavement" of the Special Provisions for the ride equation requirement.

Table 2399-4 Smoothness Pay Adjustments and Corrective Work for Bituminous Pavements		
Equation	Smoothness in/mi [m/km]	Pay Adjustment \$/0.1 mi [0.16 km]
HMA-A	< 30.0 [0.47]	400.00
	30.0 – 75.0 [0.47 – 1.18]	850.00 – 15.000 × Smoothness [850.00 – 957.450 × Smoothness]
	> 75.0 [1.18]	Corrective Work to ≤ 56.7 in/mi [0.89 m/km]
HMA-B	< 33.0 [0.52]	270.00
	33.0 – 85.0 [0.52 – 1.34]	600.00 – 10.000 × Smoothness [600.00 – 638.950 × Smoothness]
	> 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 × Smoothness [414.00 – 410.500 × Smoothness]
	> 95.0 [1.50]	Corrective Work to ≤ 63.7 in/mi [1.01 m/km]

For bituminous projects, the Engineer will not pay any positive Total Pay Adjustments 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.

Table 2399-5 Smoothness Pay Adjustments and Corrective Work for Concrete Pavements		
Equation	Smoothness in/mi [m/km]	Pay Adjustment \$/0.1 mi [0.16 km]
PCC-A	< 50.0 [0.79]	890.00
	50.0 – 90.0 [0.79 – 1.42]	2940.00 – 41.000 × Smoothness [2940.00 – 2597.800 × Smoothness]
	> 90.0 [1.42]	Corrective Work to ≤ 71.7 in/mi [1.13 m/km]

D.1.c Percent Improvement Projects

The Engineer will base pay adjustments on the segment percent improvement values. The Engineer will not require corrective work and will not assess a negative pay adjustment if the Smoothness Before Paving 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:

$$\% I = \frac{\text{Smoothness Before Paving} - \text{Smoothness After Paving}}{\text{Smoothness Before Paving}} \times 100$$

Determine the Smoothness Before Paving value before patching or other repair. Determine the Smoothness After Paving value after the completion of paving and any corrective work.

Table 2399-6 Smoothness Pay Adjustments and Corrective Work for Percent Improvement Projects		
Equation	Percent Improvement (%I)	Pay Adjustment, per \$/0.1 mi [\$0.1609 km] segment
PI	> 64.0	180.00
	33.0 to 64.0	$-295.00 + 7.420 \times (\%I)$
	< 33.0	Corrective work to %I of at least 39.8

For bituminous percent improvement projects, the Engineer will not pay any positive Total Pay Adjustments 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 33.0 percent at no additional cost to the Department as required by the Engineer.

D.2 Areas of Localized Roughness

The Engineer will evaluate 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 MRI, in/mi [m/km]	Corrective Work or Monetary Deduction, per linear 1.0 ft [0.30 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 \$100.00, as directed by the Engineer
PCC-A 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, concrete intersections constructed under traffic, 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 ALR acceptable if the retested segment contains no ALR. The Department will reduce payment for ALR 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 [6.35 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 [6.35 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 [6.35 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 corrective work 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 Smoothness values differ from the original Smoothness 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 Smoothness values differ by less than or equal to 10 percent of the original Smoothness 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.

BRIDGES & STRUCTURES

2405 PRESTRESSED CONCRETE BEAMS

2405.1 DESCRIPTION

This work consists of providing and installing prestressed concrete beams and double Tee-beams for use in bridge superstructures.

2405.2 MATERIALS

A..... Concrete.....2461

Provide concrete produced in a central-mix plant in accordance with 2461.3.F.3, "Certified Ready-Mix Plant Program." The Contractor may use Type I, Type II, or Type III portland cement.

Use Mix No. 1W36 or Mix No. 3W36 concrete for prestressed beams.

Use Mix No. 3W36 concrete for double Tee-beams.

B..... Reinforcement Bars3301

C..... Structural Steel3306

D..... High-Strength Low-Alloy Structural Steel 3309

E..... Seven-Wire Strand for Prestressed Concrete..... 3348

F..... Structural Steel Pipe..... 3362

G..... Galvanized Structural Shapes3394

H..... Galvanized Hardware.....3392

I..... Zinc-Rich Paint Systems3520

J..... Plastic Curing Blankets3756

2405.3 CONSTRUCTION REQUIREMENTS

Provide beams manufactured from a precast/prestressed concrete plant certified by the PCI or by another organization approved by the State Materials Engineer and in accordance with the following:

- (1) 2401, "Concrete Bridge Construction,"
- (2) 2471, "Structural Metals,"
- (3) 2472, "Metal Reinforcement," and
- (4) PCI Manual for Quality Control: Precast and Prestressed Concrete.

A..... General

The State Materials Engineer is the Engineer with authority concerning all matters of plant fabrication and inspection prior to delivery of the materials to the project. The Engineer has authority concerning all matters of fabrication at the project site.

Submit a written notification to the Engineer immediately after placing orders for prestressed concrete beams. Include the name and address of the supplier and the beam manufacturing location.

Notify the Materials Engineer at least 7 calendar days before the beginning manufacturing operations. If the Contractor casts the beams at the bridge site, notify the Engineer at least 7 calendar days before casting to permit inspection of the forms and reinforcement.

If casting the beams at a plant away from the bridge site, provide an office in accordance with 2031.3.A, "Basic Requirements," with air conditioning and access to sanitary facilities. The Department will not require laboratory space.

If, on any day, the Department inspects beam casting at a plant away from the bridge site and less than two beams are cast, the Department will deduct from any moneys due or becoming due to the Contractor the total cost of inspection for that day.

Provide a PCI Level II Certified Technician on site at the start of fabrication and throughout fabrication of the prestressed beams. Provide PCI Level I Certified Technicians to perform quality control functions. Provide a PCI Level II Certified Technician as a supervisor for the quality control staff.

Take precautions to prevent contamination of prestressing steel with oil, dirt, or other deleterious substances and to prevent damage that may result in weakening the prestressing steel that may result in its failure under stress. The Materials Engineer may reject nicked or kinked prestressing steel. Do not allow sparks or pieces of molten metal from welding or burning equipment to contact the prestressing steel. Do not use prestressing steel as a ground for welding equipment.

Galvanize all steel inserts or devices that will be within 1 in [25 mm] of the exposed surface of the finished structure. Galvanize or coat with zinc-rich primer all other steel inserts or devices included in the beam.

B Forms

Provide forms designed to withstand pressure from concrete, vibration, and impact without distortion. Set and maintain forms mortar tight, free of warp, and on a rigid foundation. Set the side form at right angles to the vertical axis of the beam and with the plane of bearing surfaces flat and true. Set side forms during casting as shown on the plans. Maintain side forms during casting until the concrete sets. Provide a tight fit without offset for joints in sectional forms.

Set forms for prestressed concrete beams so the dimensions of the beam after prestress transfer will conform to the plan dimensions in accordance with 2405.3.H, "Tolerances."

Treat the face of the forms in contact with the concrete with form coating material in accordance with 3902, "Form Coating Material," before setting the form in position. Clean the forms of accumulations of oil and other substances before use.

Provide beam end blocks as shown on the plans. The Contractor may increase the length of the end blocks as much as 12 in [300 mm] to accommodate sectional forms. Provide end blocks of the same length for beams of the same length in any one span.

C Steel Units

Place, support, and tie reinforcement bars for prestressed concrete beams in accordance with 2472, "Metal Reinforcement."

Cover the reinforcement bars with concrete at least 1 in [25 mm] thick.

Set sole plates for prestressed beams so that after prestress transfer the sole plate locations match the plan locations within the tolerance specified for the plan length of pretensioned beams. Place the sole plates in contact with the bottom form. Maintain position of the sole plates during placement of concrete.

Position floor drains as shown on the plans. Fasten the floor drains to the forms to ensure that concrete placement does not alter the alignment or location.

Remove loose rust, dirt, oil, and other foreign substances from prestressing tendons before erecting the beam side forms.

The Contractor may construct hold-down devices for deflected strands so that the Contractor can remove the device for a distance of at least 1 in [25 mm] from the face of the concrete and plug the hole with mortar. Use free-rolling devices (hold-down and hold-up) at all deflection points. The device may rest on the bottom form

and remain in-place. If resting the device on the bottom form, galvanize the part in contact with the form for a distance of at least 1 in [25 mm] from the form.

D.....Placement of Concrete

Cast the beams in an upright position. Place the concrete in each beam without interruption. Modify the casting procedure if the length of the beams and placement conditions cause a cold joint to form when continuing each lift full length before placing a subsequent lift.

Vibrate the concrete in each beam internally, externally, or both to produce uniformly dense concrete. Do not displace enclosures or steel units when vibrating. Internally vibrate in accordance with 2401.3.D, "Compaction of Concrete," using a vibrator with a non-metallic vibrating head no greater than 1¼ in [32 mm] in diameter operating at a frequency of at least 100 Hz [100 cps].

After striking off the top surface of the beams to the required level, work and hand float the surface to seal open tears in the surface and depress coarse aggregate. Use transverse brooming to roughen the surface.

E.....Concrete Curing

E.1.....General

Begin curing operations immediately after the concrete initially sets. Continue curing until prestress transfer.

E.2.....Curing Methods

Use any of the following to cure the beams:

- (1) Covering of burlap or canvas kept continuously wet,
- (2) Continuous water spray or mist,
- (3) Complete airtight seal using plastic curing blankets, or
- (4) The moist air or steam method of curing in accordance with 2405.E.3, "Steam Curing" which will be considered to include any methods using an external heat source.

E.3.....Steam Curing

Delay the introduction of steam into the curing enclosure, for curing purposes, until the concrete has taken its initial set and at least 3 h after placing the concrete. During the delay period, maintain a temperature within the curing chamber of at least 50° F [10° C] and no greater than 9° F [5° C] higher than the temperature of the concrete at the time of placement. The Contractor may only use steam to maintain the curing enclosure temperature within the limits.

Do not allow steam jets to impinge directly on the concrete or on the forms. Do not allow the rate of rise in temperature adjacent to the concrete to rise at rates greater than 27° F [15° C] per hour. Provide free circulation around the top, sides, and ends of the concrete units. Do not allow the temperatures adjacent to the concrete greater than 158° F [70° C]. Use saturated steam within the curing enclosure. Maintain a temperature in the concrete unit of at least 50° F [10° C] during the curing period. Do not allow a difference in temperature adjacent to the concrete within the enclosure to be greater than 9° F [5° C].

After the expiration of the steam curing period, reduce the temperature inside the chamber at a rate no greater than 40° F [22° C] per hour until the temperature inside and outside of the chamber equalize. After removing beams from the chamber, protect the beams to avoid cooling at a rate greater than 40° F [22° C] per hour until reaching the air temperature at the storage site.

If removing side forms before the completion of the steam curing cycle (including temperature taper off process), only remove and leave uncovered the minimum area of the curing enclosure at any one time needed to remove each individual form section. Close the open area in the enclosure immediately upon removing each form section or within 15 min after first uncovering the area.

When removing the beams from the casting bed during the cooling-off process, take appropriate measures to keep the beams warm during the moving operations, and immediately resume the cooling-off process at the storage area.

Provide two continuous recording thermometers for each casting enclosure with a casting bed length no greater than 100 ft [30 m]. Provide an additional thermometer for each additional 100 ft [30 m], or fraction thereof, in the length of the casting bed within each enclosure. Locate thermometers in each curing enclosure as approved by the Materials Engineer. Submit complete temperature recording charts for all cures to the Materials Engineer.

Discontinue steam curing and use one of the other approved curing methods, if the records indicate noncompliance with temperature and time element specifications for steam curing.

F Tensioning

F.1 Equipment

Tension prestressing tendons using hydraulic jacks or dynamometers and hydraulic jacks. Equip each jack pump with a hydraulic pressure gauge. Calibrate jacks, gauges, and pumps as a unit under conditions similar to operating conditions. Provide a dated, certified calibration curve for each combination used. Recalibrate equipment presenting erratic results during tensioning operations.

Ensure the hydraulic pressure gauges can accurately determine the actual stress on the jacks within a tolerance of 2 percent of the total indicated stress during final elongation of the prestressing tendons.

Calibrate the dynamometer used to measure an initial tension. Ensure the dynamometer can accurately determine the initial tension within a tolerance of 5 percent.

F.2 General Procedures

Conduct the tensioning procedure so that it is possible to compare the indicated stress on the tendons based on gauge pressures and the indicated stress based on the corresponding elongation of the tendons at any time during the tensioning operation. If the two indicated stresses, corrected for friction loss, differ by no greater than 5 percent, stress the tendons so the lower of the two indicated stresses equals the required tension in the tendon. Do not tension any tendon to an indicated stress greater than 85 percent of its specified yield point strength. If the indicated stresses differ by greater than 5 percent, stop tensioning operations. Determine the source of the discrepancy and correct it before resuming tensioning operations.

When the tensioning operation includes more than two girders with all deflection points included, demonstrate proper tension at both ends. When tensioning more than four girders with all deflection points included, measure and ensure proper elongation on the interior girders that are more than one girder from an end.

Do not tension prestressing strands in the bundled position with direct contact between adjacent strands. Maintain a clear space of at least ¼ in [6 mm] between adjacent strands during tensioning. Depress tensioned strands into a bundled position with contact between adjacent strands after the completion of tensioning.

Record the gauge pressures, indicated stresses, and elongations, and submit the record to the Materials Engineer.

The Contractor may tension strands as a group if the strands in the group are from the same manufacturer and the strands receive the same initial tension. When tensioning, consider initial strand tension no greater than 150 lb [650 N] per strand to be zero tension. If the contract requires an initial tension greater than 150 lb [650 N] per strand, use a dynamometer to measure the tension. Add the elongation due to the initial tension to the final elongation measurement.

Tension the deflected strands so that final tension is uniform in all parts of the strand. Provide freely turning rollers to reduce frictional forces at the deflection points.

Correct tension-elongation measurements for losses due to slippage of grips or anchorages, and friction to obtain the prestress force shown on the plans.

If a temperature differential in the strands at the time of tensioning and at the time of concrete placement exceeds 15° F [8° C], consider the change in the final elongation measurements to obtain the required prestress force at the time of casting. Base the change in elongation due to temperature on a 1/8 in per 100 ft [1 mm per 10 m] of strand length for each 15° F [8° C] variation in temperature. Tension prestressing tendons when the ambient air temperature is greater than 32° F [0° C] and rising.

G..... Prestress Transfer

Perform the prestress transfer after the control cylinders indicate that the concrete has reached a compressive strength of at least 4,500 psi [31 MPa] unless otherwise shown on the plans. When breaking the controls cylinders, use a testing machine that prints all test data, including time and date, directly to a printer, and initial the printout. Make the prestress transfer when the concrete is still warm and moist.

During the prestress transfer sequence keep the lateral eccentricity of the prestress to a minimum and prevent cracking in the top flange of the beams. The Contractor may perform the prestress transfer by the gradual release of hydraulic jacks, by heating exposed portions of individual strands to failure, or by a combination of these two methods. If heating the individual strands, heat in accordance with the following:

- (1) Heat each individual strand simultaneously on the strand at no less than two locations along the casting bed. Sequence heating each strand along the bed and with the sequence of perform the prestress transfer between individual strands in a manner that will prevent damage, and
- (2) Heat with a low oxygen flame played along the strand for a distance of at least 5 in [125 mm]. Control the heat to ensure that failure of the first wire in the strand does not occur for at least 5 sec after the application of heat followed by gradual elongation and failure of the remaining wires.

Completely strip the forms from the beams before beginning prestress transfer.

H..... Tolerances

After prestress transfer, check the dimensions of the prestressed concrete beam to verify that the dimensions match what the plans show within the tolerances in the PCI, *Structural QC Manual, MNL-116*.

The Engineer will measure differential camber between adjacent members of the same design with the beams erected in the final position.

The Engineer or the Materials Engineer may reject members that do not meet the dimensions shown on the plans or the specified tolerances.

I..... Rejection

The Materials Engineer may reject beams failing to meet the requirements of this section or beams showing the following after the removal of forms:

- (1) Honeycombing,
- (2) Stone pockets,
- (3) Sand streaks, or
- (4) Imperfect mixing and casting.

The Materials Engineer will not reject beams showing minor surface cavities or irregularities that do not impair the service value if repaired as approved by the Materials Engineer. Make repairs after the Materials Engineer inspects the irregularities. Use repair materials and methods approved by the Materials Engineer.

J..... Marking, Handling, Storage, and Transportation

The Department will allow beams to be moved from the casting bed to a nearby storage area after attaining the minimum compressive strength for prestress transfer. Do not transport or install beams until the beam attains a compressive strength of at least 5,000 psi [35 MPa], as evidenced by control cylinders. When casting off-site, do not ship the beam until it has reached the full design strength shown in the plans.

Mark each beam with the casting date and piecemark. If casting beams away from the bridge site, mark each beam with the name or trademark of the manufacturer and the bridge number. The Materials Engineer will stamp each approved beam with the official mark of the Department before shipment. Complete repairs before the Department stamps the unit. Do not ship beams without the Department stamp of approval. After completing the repair work, notify the Materials Engineer at least 1 full business day before intent to ship. The Engineer will perform a final inspection of units upon delivery.

Ensure markings remain in evidence after erection, but not readily visible in the completed structure.

Keep prestressed beams in an upright position at all times. Support prestressed beams during storage, lifting, and transportation at two points only. Considering beam stresses and stability, determine the support point locations in accordance with standard PCI methods.

Obtain permits as required by road authorities.

K..... Installation

Erect prestressed concrete beams in a manner that will provide safety to the workers, inspectors, and the public at all times, as well as reasonable assurance against damage to the prestressed members. Prior to the placement of diaphragms, temporarily anchor, brace and stabilize the prestressed beams as they are erected so as to preclude sliding, tipping, buckling, or other movement that may otherwise occur. If active vehicular or railroad traffic will be permitted to travel beneath beams prior to complete erection of all the beams and diaphragms in a span, submit an erection plan prepared by an engineer, thoroughly checked by a second engineer for completeness and accuracy, and certified by one of the aforementioned professional engineers licensed in the State of Minnesota which details all temporary works necessary to brace and stabilize beams. Ensure struts, bracing, tie cables, and other devices used for temporary restraint are of a size and strength that will ensure their adequacy. Arrange the work schedule so that each beam will be connected to an adjacent beam and at least two adjacent girders will be erected (including diaphragms and bolts fully tightened) and braced and stabilized in any one span before operations are suspended for the day. Install and permanently fasten the prestressed concrete beams as shown on the plans. Provide intermediate diaphragms for prestressed concrete beams as shown on the plans.

Provide structural steel shapes and plates for the steel intermediate diaphragm option in accordance with 3306, "Low-Carbon Structural Steel," or 3309, "High-Strength Low-Alloy Structural Steel." Galvanize structural steel plates and shapes in accordance with 3394, "Galvanized Structural Shapes."

Provide fasteners, including washers, for the intermediate steel option in accordance with 3391, "Fasteners." Provide fasteners meeting the requirements of ASTM A 325, Type 1. When used with galvanized structural steel, use ASTM A 325, Type 3. Galvanize fasteners for use with galvanized structural steel in accordance with 3392, "Galvanized Hardware."

Use cast-in-place anchorages to connect the steel intermediate diaphragms to the fascia beams. Provide anchorages capable of providing an ultimate pull-out strength of at least 65 kN [15 kips] per anchorage.

Provide plastic or galvanized steel material to form holes in beam webs to connect bolts for steel intermediate diaphragms.

Ensure threaded rods used to attach prestressed concrete beams to cast-in-place concrete diaphragms are either galvanized per MnDOT specification MnDOT 3392 or electroplated in accordance with ASTM B633, service condition SC4.

Completely remove or cut off flush any uncoated items, such as used for static safety lines, anchors, lifting loops, etc., prior to casting the deck.

Provide an ordinary surface finish to the exterior faces of the precast elements in accordance with 2401, "Concrete Bridge Construction". Provide a surface finish as per the special provisions with the beams in place and in conjunction with the final finish of the remainder of the structure in accordance with 2401, "Concrete Bridge Construction."

2405.4 METHOD OF MEASUREMENT

The Engineer will separately measure *Prestressed Concrete Beams Type ____* as individual units regardless of minor variations in Plan details between beams of the same type.

The Engineer will measure *Prestressed Concrete Beams ____* by summation of the individual lengths, out to out, along the centerlines of beams.

The Engineer will measure intermediate diaphragms for prestressed concrete I-beams by length based on the horizontal distance from centerline to centerline of beam along the axis of the diaphragms.

2405.5 BASIS OF PAYMENT

The contract unit price for prestressed concrete beams includes the costs of manufacturing, transporting, and erecting the beams in the final position, and the cost of temporary bracing in accordance with 2405.3.K, "Installation."

The contract unit price for prestressed concrete beams includes the cost of constructing the intermediate diaphragms complete-in-place and structural steel or concrete and reinforcement bars as shown on the plans.

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

Item No.:	Item:	Unit:
2405.501	Prestressed Concrete Beams Type ____	each
2405.502	Prestressed Concrete Beams ____in [mm]	linear foot [meter]
2405.505	Prestressed Concrete Double Tee-Beam Type ____	each
2405.511	Diaphragms for Type ____ Prestressed Beams	linear foot [meter]

2406 BRIDGE APPROACH PANELS

2406.1 DESCRIPTION

This work consists of constructing bridge approach panels.

2406.2 MATERIALS

A..... Concrete.....	2461
A.1..... Mix Designation	Mix No. 3A42
B..... Reinforcement Bars	3301
C..... Curing Materials	
C.1..... Burlap Curing Blankets	3751
C.2..... Poly Alpha Methylstyrene (AMS) Membrane Curing Compound.....	3754
C.3..... Linseed Oil Membrane Curing Compound.....	3755
C.4..... Plastic Curing Blankets.....	3756
D..... Granular Materials.....	3149
E..... Form Coating Material	3902

2406.3 CONSTRUCTION REQUIREMENTS

A..... Foundation Preparations

Excavate, shape, and compact the foundation to a firm, uniform bearing surface in accordance with 2105, "Excavation and Embankment." Construct bridge approach panels to the section and grade shown on the plans.

B.....Forms

Provide forms made of non-reactive metal, wood, or other material capable of maintaining the concrete until the concrete can retain the molded shape. Provide forms with a height at least equal to the approach panel thickness of the formed concrete as shown in the plans. Support the forms on the foundation to maintain the line and grade as shown on the plans.

On curves with a radius of 100 ft [30 m] or less, use flexible or curved forms of the radius as shown on the plans.

Before placing the concrete, coat the contact surfaces of all forms with form coating material.

C.....Placing and Finishing Concrete

Immediately before placing the concrete, thoroughly wet the foundation and forms.

Place the concrete in a manner that will prevent segregation. Consolidate the concrete to fill voids using internal vibration. Strike off the concrete to the grade shown on the plans, and float the surface smooth.

Provide the same surface texture as the bridge deck and construct in accordance with 2401, "Concrete Bridge Construction," or 2404, "Concrete Wearing Course for Bridges."

Finish edges with a $\frac{3}{8}$ in [10 mm] radius edging tool.

Keep side forms in-place for at least 12 h after casting the concrete.

D.....Joint Construction

Place joints as shown on the plans.

E.....Metal Reinforcement

Provide and place metal reinforcement as shown on the plans and in accordance with 2472, "Metal Reinforcement."

F.....Workmanship and Finish

Ensure completed concrete work is uniform in surface contour and texture and conforms to the lines and grades shown on the plans. Finish the flow line surface of gutters as necessary to eliminate low spots and avoid entrapment of water.

The Engineer will measure the surfaces of the panels with a 10-foot [3-meter] straightedge. The Engineer will consider horizontal or vertical deviations in the surface equal to or greater than $\frac{3}{8}$ in [10 mm] in any 10 ft [3 m] length of the finished concrete approach panel to be unacceptable work. Remove and replace extensive areas with deviations greater than $\frac{1}{2}$ in [13 mm]. Remove and replace unacceptable work as directed by the Engineer.

If the Engineer does not direct the removal and replacement of the unacceptable work, the Contractor may leave the work in-place and the Engineer will adjust the contract unit price as follows:

- (1) For $\frac{3}{8}$ in [10 mm] to $\frac{9}{16}$ in [14 mm] deviations, payment at 75 percent of the contract unit price.
- (2) For minor areas with deviations over $\frac{9}{16}$ in [14 mm], payment at 50 percent of contract unit price.

G.....Concrete Curing and Protection

After completing final finishing operations, cure all exposed concrete surfaces for at least 72 h. If using cementitious substitutions as defined in 2461.2.A.6, "Cementitious Substitutions," extend the minimum curing period to 96 h. Use one 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 min of concrete placement or once the bleed water has dissipated, unless the Engineer directs

otherwise in accordance with 2406.3.G.1.a, "Membrane Curing Method." Place the membrane curing compound on the edges within 30 min after permanent removal of the forms or curing blanket, unless the contract requires otherwise.

- (2) Place plastic curing blankets or completely saturated burlap curing blankets in accordance with 2406.3.G.1.b, "Blanket Curing Method," as soon as practical without marring the surface.

Failure to comply with these provisions will result in the Engineer applying a monetary deduction in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work." If the contract does not contain a separate contact unit price for *Structural Concrete*, the Department will apply a monetary deduction of \$50.00 per cu. yd [\$65.00 per cu. m] or 50 percent of the Contractor-provided invoice amount for the concrete in question, whichever is less.

Whenever weather conditions are such as to cause unusual or adverse placing and finishing conditions, 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.

G.1..... Curing Methods

G.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 with an approved airless spraying machine in accordance with the following:

- (1) At a rate of 1 gal per 150 sq. ft [1 L per 4 m²] of surface curing area.
- (2) Apply homogeneously to provide a uniform solid white opaque coverage on all exposed concrete surfaces (equal to a white sheet of typing paper). Some Mn/DOT approved curing compounds may have a base color (i.e. yellow) that cannot comply with the above requirement. In this case, provide a uniform solid opaque consistency meeting the intent of the above requirement.
- (3) If the curing compound is damaged during the curing period, immediately repair the damaged area by re-spraying.

The Engineer will approve the airless spraying machine for use if it is equipped 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.

If the Engineer determines that the initial or corrective spraying results in unsatisfactory curing, the Engineer may require the Contractor to use the blanket curing method at no additional cost to the Department.

G.1.b Blanket Curing 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.

G.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 concrete. Should any damage result, the Engineer will suspend operations

until the Contractor takes corrective action and may subject the rain-damaged concrete to 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

G.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, submit a cold weather protection plan in accordance with 2406.3.G.3.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 the Contractor takes corrective action and may subject the damaged concrete to 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

G.3.a Cold Weather Protection Plan

Submit a written cold weather protection plan to the Engineer for approval. The plan shall include a proposed time schedule for concrete placement and curing, and plans for adequately protecting the concrete during placement and curing. Do not place concrete until the Engineer approves the Contractor's cold weather protection plan.

H.....Backfill Construction

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 damage results from any of these operations, the Engineer will suspend all operations until the Contractor takes corrective action and the Engineer approves of a new method. The Engineer may subject damaged concrete to 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

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

As soon as possible after the curing is complete and without subjecting the concrete work to damaging stresses, perform the backfill or embankment construction to the elevations shown on the plans. If the contract does require a specific backfill material, use suitable grading materials from the excavations in accordance with 2105, "Excavation and Embankment." Place and compact the backfill material in accordance with 2105, "Excavation and Embankment."

Dispose of surplus excavated materials in accordance with 2105, "Excavation and Embankment."

I.....Preformed E8H Expansion Joint Sealers

Select preformed expansion joint material for the E8H expansion joints from the Approved/Qualified Products List.

Install expansion joint material in accordance with the manufacturer's recommendations and as shown on the plans.

2406.4 METHOD OF MEASUREMENT

If the contract contains a contract item (or contract items) for the construction of bridge approach panels, the Engineer will measure their construction as complete-in-place items. The Engineer will measure the total area of all panels of the same basic design. If the contract does not contain this contract item, the Engineer will measure their construction under the relevant contract items provided for pavement construction.

The Engineer will measure the length of expansion joints along the joint line as shown on the plans.

2406.5 BASIS OF PAYMENT

The cost of the following is included in the contract unit price for *Bridge Approach Panels*:

- (1) Providing and placing concrete, steel, drainage system, and polyethylene sheeting;
- (2) Constructing the integrant curb, terminal headers, and concrete sills;
- (3) Protecting and curing the concrete, and
- (4) Other incidental work not specifically included for payment under other contract items.

The cost of constructing the joints complete in-place as shown on the plans, including the providing and placing of all materials such as filler, and sealer material is included in the contract unit price for *Expansion Joints, Design E8H*.

Item No.:	Item:	Unit:
2406.553	Bridge Approach Panels	square yard [square meter]
2406.531	Expansion Joints, Design E8H	linear foot [meter]

2461 STRUCTURAL CONCRETE

2461.1 DESCRIPTION

This work consists of producing, providing, placing, curing, and protecting portland cement concrete for placement in structures, pavements and incidental construction.

2461.2 MATERIALS

A Cementitious Materials

Provide cementitious materials from certified sources listed on the Approved/Qualified Products list.

Use Type I or Type I/II portland cement to produce Type 1 non-air-entrained concrete.

Use Type I or Type I/II portland cement and an air-entraining admixture listed on the Approved/Qualified Products List to produce Type 3 air-entrained concrete.

Use Type III portland cement as allowed by the contract or the Engineer.

A.1 Portland Cement3101

A.2 Ground Granulated Blast Furnace Slag3102

A.3 Blended Hydraulic Cement3103

A.4 Fly Ash3115

A.5 Cementitious Content

Provide concrete with the minimum cementitious content for the grades and slumps of concrete in accordance with Table 2461-1:

Table 2461-1 Minimum Cementitious Content, lb per cu. yd [kg per cu. m]								
Specified Slump Limit, in [mm]	Grades							
	U	V	W	X	Y	A	B	C
1 [25]	800 [475]	730 [435]	—	—	—	—	—	—

Table 2461-1 Minimum Cementitious Content, <i>lb per cu. yd [kg per cu. m]</i>								
Specified Slump Limit, in [mm]	Grades							
	U	V	W	X	Y	A	B	C
2 [50]	830 [490]	765 [455]	660 [390]	630 [375]	570 [340]	530 [315]	490 [290]	420 [250]
3 [75]	850 [505]	730 [475]	695 [410]	665 [395]	605 [360]	560 [335]	515 [305]	445 [265]
> 3 [75]	—	—	730 [475]	700 [415]	640 [380]	590 [350]	540 [320]	470 [280]

Except for grout mixtures, limit the maximum cementitious content for a cubic yard [cubic meter] of concrete to 850 lb [505 kg].

A.6 Cementitious Substitutions

The Contractor may replace Type I or Type I/II portland cement with other cementitious materials in accordance with the following restrictions:

- (1) Maximum of 15 percent substitution of Class C or Class F Fly Ash, on a one for one basis, by weight of the designed portland cement;
- (2) For Department designed mixes, the Department will adjust the batch weight of coarse aggregates to compensate for volume changes due to cementitious substitutions;
- (3) Maximum of 33 percent substitution of Class C or Class F Fly Ash for concrete pavement, on a one for one basis, by weight of the designed portland cement;
- (4) Maximum of 35 percent substitution of slag, on a one for one basis, by weight of the designed portland cement; and
- (5) Ternary mixes (portland cement and two other supplementary cementitious materials) are allowed when approved by the Engineer, in conjunction with the Concrete Engineer, or required by or allowed in the contract.

B Fine Aggregate 3126

C Coarse Aggregate 3137

Unless otherwise required by the contract, the Contractor may select the class of coarse aggregate as defined in 3137.2.B, "Classification."

D Water.....3906

E Concrete Admixtures.....3113

The Contractor may use the following admixtures listed on the Approved/Qualified Products List:

- (1) Type A, "Water Reducing and Mid Range Water Reducing Admixtures,"
- (2) Type B, "Admixtures Identified as Hydration Stabilizers,"
- (3) Type D, "Water Reducing and Retarding Admixtures," and
- (4) Type S, "Viscosity Modifying Admixtures."

Use of any other admixtures in the concrete requires approval of the Concrete Engineer unless otherwise required by or allowed in the Contract.

When incorporating admixtures into the concrete:

- (1) Use admixture dosage rates recommended by the manufacturer;

- (2) Add all admixtures at the plant;
- (3) Provide admixture additions at the job site that are the same products as originally incorporated into the mix; and
- (4) Use calcium chloride in concrete as approved by the Engineer. Do not use calcium chloride in units containing prestressing steel or in bridge superstructure concrete.

E.1 Use of Additional Admixtures

On a case by case basis, the Engineer will consider the use of the following admixtures, added either at the plant or at the job site, as listed on the Approved Products list:

- (1) Type C, "Accelerating Admixtures,"
- (2) Type E, "Water Reducing and Accelerating Admixtures,"
- (3) Type F, "Water Reducing, High Range Admixtures," and
- (4) Type G, "Water Reducing, High Range and Retarding Admixtures."

E.1.a Delivery Time Beyond 90 Minutes

If the haul time does not facilitate mixing and placing the concrete within 90 minutes, perform the following procedures for pre-qualifying a concrete mix to extend the delivery time to 120 minutes. Extending the delivery time beyond 120 minutes will require additional testing at 30 minute intervals up to the maximum desired delivery time as directed by the Concrete Engineer.

- (1) Provide a contractor mix design in accordance with 2461.3.G.2 for each combination of materials;
- (2) Specification 2461.3.D is modified to allow up to 25% fly ash replacement for cement. All other requirements of 2461 apply;
- (3) Laboratory trial batching on the proposed mix includes the following testing requirements:
 - (a) Perform all laboratory trial batching at an AMRL accredited laboratory;
 - (b) Perform all plastic concrete testing after adding all admixtures to the concrete mixture;
 - (c) Perform slump, air content, unit weight, and temperature testing immediately after batching, at 90 minutes, and at 120 minutes;
 - (d) Fabricate concrete cylinders for compressive strength at 90 minutes and at 120 minutes (sets of 3) and cylinders for hardened air content testing at 90 minutes and at 120 minutes (sets of 5);
 - (e) Test the cylinders for compressive strength at 28 days;
 - (f) Determine the hardened air content (ASTM C457) at a minimum of 7 days. The Contractor is required to test 2 samples representing 90 minutes and 2 samples representing 120 minutes and provide MnDOT with the other 6 samples for testing at their discretion. Retain any hardened concrete test specimens for a minimum of 90 days for MnDOT to examine at their discretion;
 - (g) Ensure the admixture manufacturer's technical representative is present during the trial batching;
 - (h) Contact the MnDOT Concrete Engineering Unit a minimum of 2 days before mixing. This same 2 day notification is required before any physical testing on hardened concrete samples; and
 - (i) Once accepted by the Concrete Engineer, the Department will consider the laboratory trial batching acceptable for use for 5 years, unless it is determined the material sources have changed significantly since the initial laboratory testing and acceptance. The Engineer will require field trial batching on all projects.
- (4) Field trial batching on the proposed mix for each specific project shall include batching in the presence of the Engineer and the following:
 - (a) Provide a QC Plan for extending the delivery time beyond 90 minutes;
 - (b) Mix and transport the concrete using the same materials as were utilized in the laboratory trial batching;
 - (c) Batch a minimum 5 cu. yd (4 cu. m) of concrete utilizing the same methods intended for use when supplying concrete placed into the permanent work;
 - (d) Maintain the ready mix truck in transit; by either driving around the yard or on the roadway; and maintain the drum speed at 5 to 7 revolutions per minute for the entire 120 minutes;

- (e) Perform all plastic concrete testing after adding admixtures to the concrete mixture;
 - (f) Perform slump, air content, unit weight, and temperature testing at 90 minutes and 120 minutes;
 - (g) Fabricate concrete cylinders for compressive strength at 90 minutes and 120 minutes (sets of 3) and cylinders for hardened air content testing at 90 minutes and 120 minutes (sets of 2);
 - (h) Test the cylinders for compressive strength at a minimum of 7 days;
 - (i) Determine the hardened air content (ASTM C457) at a minimum of 7 days. The Contractor is required to test 1 sample representing 90 minutes and 1 sample representing 120 minutes and provide MnDOT with the other 2 samples for testing at their discretion. Retain any hardened concrete test specimens for a minimum of 90 days for MnDOT to examine at their discretion;
 - (j) Incorporate the trial batch concrete into other work with the approval of the Engineer; and
 - (k) The Contractor must demonstrate to the Engineer the ability to properly mix, control, and place the concrete.
- (5) The Concrete Engineer will review the trial batch results and all related concrete testing for compliance with the QC Plan and the Contract. Final approval of the mixture is based on satisfactory field placement and performance.

F Concrete Mix Designs

F.1 Department Designed

The Department will provide the estimated composition of concrete mixes unless otherwise required by the contract.

The Department may adjust the mix composition of the concrete without adjusting the contract unit price for any contract items.

F.1.a Concrete Yield

The Department defines concrete yield as the ratio of the volume of mixed concrete, less accountable waste, to the planned volume of the work constructed. The Department will not assume responsibility for the yield from a given volume of mixed concrete.

F.1.b High-Early Strength Concrete

When the Engineer requires high-early strength concrete, the concrete is designed in accordance with the following:

- (1) Increasing the cement content of the concrete up to 30 percent; using an approved accelerator as allowed by the Engineer, in conjunction with the Concrete Engineer; or both.
- (2) Using 100 percent portland cement, unless allowed by the contract or the Engineer.
- (3) A maximum cement content for a cu yd [cu m] of concrete not to exceed 900 lb [535 kg].
- (4) A water/cement ratio not to exceed 0.38 for Type 3 Concrete unless otherwise required by the contract.

F.2 Contractor Designed

Design the concrete mix based on an absolute volume of 27.00 cu. ft \pm 0.10 cu. ft [1.000 cu. m \pm 0.003 cu. m] for the following:

- (1) Concrete paving mixes in accordance with 2301, "Concrete Pavement;"
- (2) Concrete mixes with an anticipated or required 28-day compressive strength of at least 5,000 psi [34 MPa];
- (3) Precast concrete in accordance with 2405, "Prestressed Concrete Beams," 2412, "Precast Concrete Box Culverts," 3236, "Reinforced Concrete Pipe," 3238, "Precast Concrete Box Culverts," 3621, "Concrete Masonry Units," 3622, "Sectional Concrete Manhole and Catch Basin Units," and 3630, "Precast Concrete Median Barriers;"
- (4) Colored concrete;
- (5) Stamped concrete;
- (6) Cellular Concrete Grout – Controlled Low Strength Material (CLSM);

- (7) Extended Delivery Times Beyond 90 Minutes; and
- (8) Concrete as otherwise required by the contract.

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

The Concrete Engineer, in coordination with the Engineer, will review the mix design submittal and will 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 the concrete for payment based on satisfactory field placement and performance.

F.3 Classification of Concrete

The Department will classify concrete by type, grade, consistency, and aggregate size. Refer to the mix number and Table 2461-2 to determine the mix requirements for each item of work.

Table 2461-2 Mix Number Identification				
First Digit	Second Digit	Third Digit	Fourth Digit	Additional Digits
Type	Grade	Slump range	Coarse aggregate gradation range	Class A coarse aggregate when required, modified mix designation, or both

Refer to individual contract items in the Standard Specification for Mix Numbers. Deviations from the specified Mix Numbers require coordination with the Concrete Engineer.

If the contract does not show a concrete mix number, provide Type 3, Grade Y concrete with a slump and aggregate gradation determined by the Engineer.

The Department will designate grout by type and grade followed by the word "GROUT." Do not provide grout containing coarse aggregate. If the plans do not show a type or grade for grout, provide 3A GROUT.

F.3.a Type Designation

Provide Type 1 or Type 3 concrete in accordance with Table 2461-3:

Table 2461-3 Concrete Type Designation		
Concrete Type	Target Air Content*, %	Maximum Water/Cement Ratio #
1	2.0	≤ 0.53 for 1A43 ≤ 0.68 for 1C62 ≤ 0.64 for 1C Grout
3	6.5 †	≤ 0.45 †
* For concrete mix design purposes only. The water/cement ratio is defined as the ratio of the total water weight to the total cementitious weight. † Unless otherwise required by 2301 or elsewhere in the contract. # The maximum water/cement ratio for machine placed concrete is 0.42.		

F.3.b Grade Designation

The Department will designate concrete grade using a letter to represent the anticipated compressive strength and the minimum cementitious content in accordance with 2461.2.A.5, "Cementitious Content," and Table 2461-4:

Table 2461-4 Concrete Grade Designation		
Concrete Grade	Type 1 Anticipated Compressive Strength, <i>psi [MPa]</i> *	Type 3 Anticipated Compressive Strength, <i>psi [MPa]</i> *
U	6,300 [43]	5,600 [39]
V	6,000 [41]	5,300 [37]
W	5,700 [39]	5,000 [34]
X	5,400 [37]	4,700 [32]
Y	5,000 [34]	4,300 [30]
A	4,500 [31]	3,900 [27]
B	4,100 [28]	3,400 [23]
C	3,200 [22]	2,700 [19]
* Anticipated minimum strength produced in accordance with the Department specifications and cured for 28 days under laboratory conditions.		

The Concrete Engineer, in coordination with the Engineer, may increase the cement content for concrete with test cylinder results less than the anticipated compressive strength in accordance with Table 2461-4, "Concrete Grade Designation." The Contractor may request an increase in the cement content as approved by the Engineer, in conjunction with the Concrete Engineer.

F.3.c Slump Designation

Refer to the slump designation for the upper limit of the slump range without a water reducer in accordance with Table 2461-5:

Table 2461-5 Slump Designation	
Slump Designation	Slump Range without Water Reducer, in [mm]
1	½ – 1 [12 – 25]
2	1 – 2 [25 – 50]
3	1 – 3 [25 – 75]
4	2 – 4 [50 – 100]
5	2 – 5 [50 – 125]
6	3 – 6 [75 – 150]

F.3.d Coarse Aggregate (CA) Designation

Refer to the coarse aggregate designation for the range of optional coarse aggregates gradations allowed in the mix in accordance with Table 3137-4, "Coarse Aggregate Designation for Concrete," and Table 2461-6:

Table 2461-6 Coarse Aggregate Designation for Concrete	
Range	Optional Coarse Aggregate Designation
0	CA-00 only
1	CA-15 to CA-50, inclusive
2	CA-15 to CA-60, inclusive
3	CA-35 to CA-60, inclusive
4	CA-35 to CA-60, inclusive
5	CA-45 to CA-60, inclusive
6	CA-50 to CA-70, inclusive
7	CA-70 only
8	CA-80 only

F.3.e Additional Designations

For mix designs that require a specified class of coarse aggregate as defined in 3137.2.B, "Classification," an additional letter will follow the fourth digit of the Mix Number such as "A" (Class A Aggregate Requirement).

The Engineer may identify special concrete mix designations with additional letters following the last digit such as "HE" (High Early), "WC" (Water/Cement Ratio), "HPC" (High Performance Concrete), "MS" (Microsilica), or others.

2461.3 CONSTRUCTION REQUIREMENTS

A Batching Equipment

A.1 Mixer Requirements

Provide stationary mixers or truck mixers.

A.2 General Condition

Maintain mixers as necessary to detect changes in condition due to accumulations of hardened concrete or mortar and examine to detect wear of blades.

Replace or recondition pickup and throwover blades in mixers with a rated capacity less than 14 cu. ft [0.40 cu. m] showing a blade wear loss of greater than ½ in [13 mm], and pickup and throwover blades in mixers of greater capacity, showing a blade wear loss of no greater than ¾ in [19 mm] from the original factory dimensions.

A.3 Manufacturer's Rating Plate

Provide mixers that include the manufacturer's rating plate, showing the following information:

- (1) Serial number of the unit,
- (2) Mixing speed of the drum or paddles, and
- (3) Maximum capacity in terms of volume of mixed concrete.

A.4 Drum Speed for Stationary Mixers

Operate the drum speed in the mixer as specified by the manufacturer or as directed by the Engineer.

A.5 Auxiliary Equipment Requirements

Provide mixers equipped with the following:

- (1) Timing device,
- (2) Discharge locking device,
- (3) Water measuring device that operates mechanically and automatically during each batching cycle, and
- (4) A graduated adjustable indicator device to represent the volume of discharge in increments no greater than ¼ gal [1 L] in full view.

A.6 Mixer Capacity

Do not exceed the manufacturer's rated capacity of the mixer when mixing a single batch of concrete.

Batch concrete in volumes the mixer can accommodate without spilling, leaking, or segregating during the charging, mixing, or discharging operations. Provide mixers with a capacity of at least 1 sack [0.25 cu. m].

A.7 Mixing Time

The Department defines the mixing time as the time period beginning when the cement and aggregates enter the mixer drum and ending when the discharge begins.

Refer to the manufacturer's recommended minimum mixing time for single drum and dual drum mixers. In the absence of manufacturer's recommendation, the Engineer will designate the minimum mixing time. The minimum mixing time for any concrete batch is 60 s. The Contractor may reduce the manufacturer's recommended minimum mixing time or the Engineer designated mixing time if the Contractor obtains uniform mixing in accordance with 2461.3.E, "Mixing Requirements," and as approved by the Engineer, in conjunction with the Concrete Engineer.

If there is evidence of inadequately mixed concrete (unmixed or partially mixed materials) during concrete placement, the Engineer may direct an increase in the mixing time.

A.8 Turbine Type Mixers

Provide turbine type mixers meeting the applicable requirements for conventional type mixers (2461.3.A.1 through 2461.3.A.7) and in accordance with this subsection (2461.3.A.8). Maintain the mixer drum in a cylindrical shape within $\frac{3}{4}$ in [19 mm] from the original factory dimensions at any point. Maintain the mixer discharge gate in a mortar tight condition in the closed position. Replace or recondition mixer paddles showing a wear loss greater than $\frac{1}{2}$ in [13 mm] from the original factory dimensions.

Add the mixing water to the batch materials in a manner that distributes the water to the inner or central areas of the drum. Start the flow of water before introducing the solid batch materials into the mixer drum.

During mixing, operate the paddles at a speed between 20 revolutions and 30 revolutions per minute. After adding the batch materials to the drum, mix the concrete for an additional 60 s.

A.9 Horizontal Axial-Revolving Blade Type Mixers

Provide horizontal axial-revolving blade type mixers in accordance with the applicable requirements for conventional type mixers (2461.3.A.1 through 2461.3.A.7) and in accordance with this subsection (2461.3.A.9).

Charge the water, aggregates, and cement in the sequence approved by the Engineer. Test the concrete uniformity as directed by the Engineer. The Engineer will use concrete uniformity tests to determine the minimum mixing time.

B Transportation Units

B.1 General Requirements

Equip transportation units intended for both mixing and agitating with watertight revolving drums mounted and powered and fitted with properly designed mixing blades in accordance with 2461.3.A.1 through 2461.3.A.7. Provide units capable of combining all the ingredients into a homogeneous mixture and designed to provide two drum speeds, one for mixing and the other for agitating. Provide units capable of delivering the concrete without segregation or loss of any of the batch materials.

Equip the mixer drum with a working counting device to record the number of revolutions.

Equip dump trucks and agitator trucks with vibrators to aid in discharge, are mortar tight, capable of complete discharge of the concrete and in accordance with 2301.3.F.

B.2 Capacity of Transportation Units

Refer to the truck mixer manufacturer's certification plate attached to the unit for the maximum capacity of the unit. If the unit will not satisfactorily mix the maximum volume shown, reduce the batch volume to allow proper mixing or discontinue use of the mixing unit as directed by the Engineer until the problem is corrected.

C Handling and Storing Materials

C.1 Batch Material Requirements

Do not change the source, kind or gradation of batch materials after the start of concrete production for the work unless otherwise approved by the Engineer. If the Engineer approves use of different material, completely exhaust the supply on hand before changing to the different material.

If delivering freshly washed aggregates to the batching plant, drain the aggregates for at least 12 h before using in the batching operation. If draining freshly washed aggregates at the site of the batching plant, completely separate the drained material from the undrained materials, and provide for the disposal of water that accumulates from the drainage of materials.

Provide smooth, firm, and well-drained stockpile sites cleared of vegetable and extraneous matter. Where the natural foundation is unsatisfactory, as determined by the Engineer, construct the stockpiles on suitable platforms. Construct suitable bulkheads or partitions to separate different kinds of aggregate, gradation, or water content.

Construct stockpiles by methods that hold segregation and degradation to a minimum. If the Engineer sees segregation or degradation, the Engineer may designate that pile as unacceptable for use.

Do not use aggregates used to construct runways for loading or hauling equipment in concrete batches.

Use of aggregates from the bottom 1 ft [0.3 m] of a stockpile placed on an unprepared surface in concrete batches is allowed only under the Engineer's direct supervision and if the material meets all requirements of 3126, "Fine Aggregate for Portland Cement Concrete," and 3137, "Coarse Aggregate for Portland Cement Concrete."

Provide aggregates in accordance with the specified gradation requirements.

The Engineer will consider aggregates unacceptable if the variation in moisture content carried by any of the aggregates causes a marked variation in the consistency of successive batches of the mixed concrete, and will suspend operations until corrected.

C.2 Concrete Temperature Control

Produce concrete at temperatures from 50 °F to 90 °F [10 °C to 30 °C] and maintain temperatures until deposited in the work.

If necessary to maintain placement temperature, uniformly heat or cool the water, aggregates, or both, before introduction into the mixer. Control the temperature of the mixing water during heating or cooling.

Use aggregate at temperatures from 32 °F to 130 °F [0 °C to 55 °C]. Do not allow cementitious material to contact other batch material when the aggregate temperature exceeds 130 °F [55 °C].

Do not heat the cement, add salt, or add chemical admixtures to the concrete mix to prevent freezing.

Use a heating system to heat batch materials as approved by the Engineer. Do not use steam jets to spot heat the material as the work progresses.

Do not place mixer heaters intended for heating the batch materials in the mixer drum.

D Batching Requirements

Calibrate weighing equipment in accordance with 1901, "Measurement of Quantities." Inspect and calibrate the scales in accordance with the Concrete Manual.

D.1 Batching by Weight

D.1.a Proportioning Methods

Proportion concrete batch materials by weight in a central plant or by volume as directed by the Engineer, in conjunction with the Concrete Engineer.

D.1.b Weighing Equipment and Tolerances

Weigh or measure concrete mixture ingredients using load cells or meters for ready-mix and paving concrete to within the targeted batch weight in accordance with the following:

- (1) Water – 1 percent,
- (2) Cement – 1 percent,
- (3) Other cementitious materials – 3 percent,
- (4) Aggregates – 2 percent, and
- (5) Admixtures – 3 percent.

D.1.c Batching of Mixing Water

Measure the mixing water on scales or water metering devices containing the following:

- (1) A discharge indicator capable of being set to within 1 gal [5 L] of a predetermined quantity,
- (2) A positive automatic shutoff valve, and
- (3) An approved inspection seal on the scale or water metering device dating the time of the previous calibration and adjustment

An authorized service agency will calibrate the water meter every 6 months and make adjustments as necessary before use meeting the requirements of the weighing procedure in the Concrete Manual.

Check the water meter for accuracy at least once each month as the work progresses.

D.1.d Batching of Cementitious Materials

Weigh the cementitious material independently of the aggregates in separate compartments or on separate scales.

If the Contractor weighs the cement first and then separately records the weights of each individual cementitious material, the Contractor may weigh the cementitious materials cumulatively as approved by the Engineer, in conjunction with the Concrete Engineer.

D.1.e Batching of Aggregates

If the Contractor records each individual fraction weight of aggregates separately, the Contractor may weigh aggregates cumulatively as approved by the Engineer, in conjunction with the Concrete Engineer.

D.1.f Admixture Proportioning

If using two or more admixtures in a single concrete batch, add each admixture separately to prevent interaction of the different admixtures before mixing with other batch materials. Agitate admixtures to ensure homogeneous concentrations in accordance with the manufacturers recommendations.

Incorporate admixtures to the batch mix in liquid form. Maintain admixture solutions at a uniform concentration at all times. Use the solution concentration and proportions designated by the manufacturer.

If using a mechanical dispenser for proportioning Class I or Class II admixtures, provide a site gauge or meter. Have the admixture manufacturer check admixture dispensers yearly to determine accuracy and ensure unobstructed flow.

D.2 Batching by Volume

Proportion concrete for bridge deck overlays by volume or as required by the contract.

If the Contractor calibrates the mixer for the specific batch materials in use, the Contractor may proportion concrete on other items of work by volume as approved by the Engineer in writing.

The Engineer will approve all methods and equipment used in volumetric proportioning.

Determine all material proportions and calibration settings on the basis of 100 lb [100 kg] of cementitious material.

Provide and use only sacked cement in the original mill containers unless the Contractor calibrates the mixer for the specific materials in use. Do not use fractional sacks.

Increase the cementitious content by 10 percent in the computation of volume proportions unless the Contractor calibrates the mixer for the specific materials in use.

E Mixing Requirements

The Engineer may check the water measuring equipment for accuracy before mixing operations begin and at any other time the Engineer considers necessary.

Mix concrete by one of the following methods:

- (1) A central plant (stationary plant),
- (2) Entirely or in part in truck mixers, or
- (3) At the construction site.

Do not allow the mixing batch to merge or intermix with the subsequent dry batch during mixing.

Discharge water remaining in the drums before batching.

Mix concrete to provide a mixture that is homogeneous and uniform in color. The Engineer will reject concrete batches that show a marked variation in consistency or evidence of improper mixing as unacceptable work in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

After completely mixing the concrete, either in a central plant mixer or truck mixer, continuously agitate while in transit to the point of placement until the concrete is discharged from the unit, unless otherwise allowed by the Engineer, in conjunction with the Concrete Engineer.

If the mixing does not appear uniform, perform slump tests at the 15 percentage point and the 85 percentage points during unloading. If the results show a slump variation greater than 1½ in [38 mm], stop work and correct the mixing unit.

Produce concrete in such quantity and at such a rate as proper placement and finishing will permit. Do not re-temper partially set concrete.

Do not hand mix concrete.

E.1 Mixing In Truck Mixer

Charge the materials into the truck mixer drum by introducing sufficient water before adding solid materials. Perform charging operations without losing materials.

Leave the truck mixer at the plant site for a minimum of 5 min or 50 revolutions during the mixing period. Transport the concrete at agitating speed to the point of placement.

F Certified Ready-Mix Concrete

F.1 Definitions

The Department defines ready-mix concrete as one of the following:

- (1) Central-mixed concrete proportioned and mixed in a stationary plant and hauled to the point of placement in revolving drum agitator trucks or a truck mixer, or
- (2) Truck-mixed concrete proportioned in a stationary plant and fully mixed in truck mixers.

Table 2461-7 defines commonly used certified ready-mix terms.

Table 2461-7 Certified Ready-Mix Terminology	
Term	Definition
Mix design water	The maximum allowable water content for 1 cu. yd [1 cu. m] of concrete in accordance with Mn/DOT Form TP 02406, <i>Estimated Composition of Concrete Mixes</i> .
Total moisture factor	Factor used to determine total amount of water carried by a given wet aggregate.
Absorption factor	Factor used to determine the water contained within the pores of the aggregate and is held within the particles by capillary force.
Free moisture	The water that is carried on the surface of the aggregate that becomes part of the total water.
Batch water	Water actually batched into the truck by the batcher.
Total water	Batch water added to free moisture. Total water may also include the water used in diluting admixture solutions.
Temper water	Water added in mixer to adjust slump.
Total actual water	The water in the concrete mixture at the time of placement from any source other than the amount absorbed by the aggregate. It includes all batch water placed in the mixer, free moisture on the aggregate and any water added to the ready mix truck prior to placement.
Ready-Mix Producer or "Producer"	Party that is producing the concrete for the Contract. It is understood that the Ready-Mix Producer is the agent of the Contractor.

F.2 General Requirements

Supply ready-mix concrete in accordance with 2461.3.F.3, "Certified Ready-Mix Plant Program."

The Engineer will reject ready-mix concrete delivered to the work site that does not meet the specified requirements for delivery time, consistency, quality, air content, or other properties as unacceptable work in accordance with 1512, "Unacceptable and Unauthorized Work."

Provide batches for a delivered load of concrete in sizes of at least 1 cu. yd [1 cu. m].

F.3 Certified Ready-Mix Plant Program

Provide ready-mix concrete produced by a certified ready-mix plant. Perform quality control of concrete production under a certification program for ready-mix concrete plants.

Complete all concrete plant documentation utilizing the Concrete Ready-mix Plant QC Workbook available from the MnDOT Concrete Engineering website. Electronically submit the QC Workbook to the Engineer by the Tuesday immediately following the previous week's production.

F.3.a Plant Certification

Before concrete production each season, ensure the producer performs the following:

- (1) Performs an on-site inspection at the concrete plant with the Engineer and completes a Mn/DOT Form 2163, *Concrete Plant Contact Report*.
- (2) Signs the report certifying compliance with the Certified Ready Mix requirements and continual maintenance of the plant. The Engineer will also sign Mn/DOT Form 2163, *Concrete Plant Contact Report*.
- (3) Provides continuous access on-site to the MnDOT Concrete Manual available from MnDOT's website.
- (4) Supply the Certified Ready-Mix Plant with a working email address.

- (5) Keeps plant reports, charts, and supporting documentation on file at the plant site for 5 calendar years
- (6) Provides electronic scales for weighing all materials.

F.3.b 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 facilities in accordance with 1604, "Plant Inspection – Commercial Facility," for the use of the plant technician in performing tests.

Ensure the producer provides technicians with certification 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 certification at least meeting Mn/DOT Concrete Plant Level 1 to perform all of the duties in accordance with the Concrete Manual.

Ensure the producer performs testing in accordance with the Concrete Manual and determines testing rates meeting 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.

Perform testing at the certified ready-mix plant site. Perform additional testing as directed by the Engineer. The Engineer may oversee the quality control sampling process.

Provide equipment and perform calibrations meeting the requirements of the following:

- (1) AASHTO T 27, "Sieve Analysis of Fine and Coarse Aggregates,"
- (2) AASHTO T 255, "Total Moisture Content of Aggregate by Drying,"
- (3) AASHTO M 92, "Wire-cloth Sieves for Testing Purpose," and
- (4) AASHTO M 231, "Weighing Devices Used in the Testing of Materials."

F.3.c Gradations

Determine the gradation of the fine aggregates and the coarse aggregates as required by the contract. Use mechanical shakers for sieve analysis of fine and coarse aggregates.

Identify quality control companion samples with the following information:

- (1) Date,
- (2) Test number,
- (3) Time,
- (4) Type of material,
- (5) Plant, and
- (6) Sampling location.

Document gradation results on Mn/DOT Form 2449, *Weekly Concrete Aggregate Report*.

Chart all producer gradation results and Department verification gradation results of the coarse aggregate and the No. 8 [2.36 mm], No. 30 [600 µm], and No. 50 [300 µm] sieves of the fine aggregate.

The producer may request a reduction in testing rates as approved by the Engineer, in conjunction with the Concrete Engineer.

If the gradation tests on split samples from quality control or verification samples result in a variation between the producer and the Department greater than that set forth in Table 2461-8, the parties shall follow the procedures for test result dispute resolution available from the Mn/DOT Concrete Engineering website.

Table 2461-8	
Allowable Variations on Percent Passing Sieves	
Sieve Size	Allowed Percentage
2 in – 3/8 in [50 mm – 9.5 mm]	± 6
No. 4 – No. 30 [4.75 mm – 600 µm]	± 4
No. 50 [300 µm]	± 3
No. 100 [150 µm]	± 2
No. 200 [75 µm]	± 0.6

F.3.c.(1) Non-conforming Material

Only place concrete meeting the gradation requirements in the work. If the Contractor places concrete not meeting the gradation requirements into the work, the Engineer will not accept nonconforming concrete at the contract unit price.

For concrete not meeting the required gradation, the Engineer will make determinations regarding the disposition, payment, or removal. The Department will adjust the contract unit price for the concrete contract item in accordance with Table 2461-9 and Table 2461-10. When there is not a separate *Structural Concrete* contract unit price for an item of work or the concrete is a minor component of the contract unit price, the Department will reduce payment based on a concrete price of \$100.00 per cu. yd [\$130.00 per cu. m] or the Contractor-provided invoice amount for the concrete in question, whichever is less.

Table 2461-9	
General Concrete for Individual Aggregate Fractions	
Fine and Coarse Aggregate Specification Sieves other than Fine Aggregate No. 200 [75 µm]	
Outside of Specification, %	Adjusted Contract Unit Price
≤ 3	The Department will pay 98 percent of the relevant contract unit price for concrete placed as approved by the Engineer.
4 – 6	The Department will pay 95 percent of the relevant contract unit price for concrete placed as approved by the Engineer.
7 – 10	The Department will pay 90 percent of the relevant contract unit price for concrete placed as approved by the Engineer.
> 10	The Department will pay 75 percent of the relevant contract unit price for concrete placed as approved by the Engineer.

Table 2461-10	
General Concrete for No. 200 [75 µm] Sieve of Fine Aggregate	
Outside of Specification, %	Adjusted Contract Unit Price
< 0.3	The Department will pay 98 percent of the relevant contract unit price for concrete placed as approved by the Engineer.
0.4 – 0.6	The Department will pay 95 percent of the relevant contract unit price for concrete placed as approved by the Engineer.
0.7 – 1.0	The Department will pay 90 percent of the relevant contract unit price for concrete placed as approved by the Engineer.
> 1.0	The Department will pay for 75 percent of the relevant contract unit price for concrete placed as approved by the Engineer.

If failure occurs on the fine aggregate No. 200 [75 µm] sieve and on other sieves concurrently, the Department will only reduce the price based on the larger percentage deduction.

The Engineer, in conjunction with the Concrete Engineer, will determine adjusted contract unit prices for coarse aggregate quality failures in accordance with 1503, “Conformity with Contract Documents,” and 1512, “Unacceptable and Unauthorized Work.”

F.3.d Moisture Content

Ensure the producer performs the following:

- (1) Determines the moisture content using the oven-dry method in all fractions of the aggregate.
- (2) Documents moisture tests on Mn/DOT Form 2152, *Concrete Batching Report*.

In addition to the oven-dry moisture test, the producer may obtain the moisture content in the fine aggregate using a moisture probe.

To obtain approval for the use of a moisture probe, ensure the producer calibrates the moisture probe before each construction season meeting the requirements of the Concrete Manual. Ensure the producer verifies both the probe moisture content and the oven-dry verification moisture test and records in the Producer plant diary.

F.3.e Plant Diaries

Provide daily plant diaries in accordance with the Concrete Manual using an approved form from the Mn/DOT’s Concrete Engineering website.

F.3.f Batch Weight Verification

The Engineer will observe the batching process to verify weights shown on the Certificate of Compliance.

The Engineer will observe the actual water batched during each collection of verification gradations in accordance with the following:

- (1) Watching the ready-mix truck reverse the drum after washing,
- (2) Verifying use of the current moisture test,
- (3) Verifying that any additional water added to adjust the slump is recorded, and
- (4) Validating water weights on the load batched and comparing the total water with the design water.

The Engineer will document the actual water batched on Mn/DOT Form 24143, *Weekly Certified Ready-Mix Plant Report* and submit a copy to the Engineer to provide to the Concrete Engineer.

The Engineer will provide plant diaries in accordance with the Concrete Manual.

F.3.g Certificate of Compliance

Provide a computerized Certificate of Compliance with each truckload of ready-mixed concrete at the time of delivery. The Department defines computerized to mean a document that records mix design quantities from load cells and meters.

If the computer that generates the Certificate of Compliance malfunctions, the Engineer may allow the Contractor to finish any pours in progress if the producer issues a handwritten Mn/DOT Form 0042, *Certificate of Compliance* with each load. Do not allow the producer to begin new pours without a working computerized Certificate of Compliance.

Provide a computerized Certificate of Compliance from the producer for each item of information, including the following:

- (1) Name of the ready-mix concrete plant.
- (2) Name of the Contractor.
- (3) Date.
- (4) State Project Number (SP) or (SAP).
- (5) Bridge Number (if applicable).
- (6) Time concrete was batched.
- (7) Truck number.
- (8) Quantity of concrete in this load.
- (9) Running total of each type of concrete, each day for each project.
- (10) Type of concrete (Mn/DOT Mix Designation Number).
- (11) Cementitious materials using Mn/DOT Standard Abbreviations.
- (12) Admixtures using Mn/DOT Standard Abbreviations.
- (13) Aggregate sources using 5 digit State Pit Numbers.
- (14) Admixture quantity in fluid ounces per 100 lb [milliliters per kilogram] or ounces per cubic yard [milliliters per cubic meter].
- (15) Batch information for materials using Mn/DOT standardized labels to represent each column in Table 2461-11. Present the information in the order listed across the page (a through k) or print the information using two lines provided that the materials are identified in each line of information.

Table 2461-11			
Standardized Certificate of Compliance Labels			
	Formula Letter	Formula	Standard Label
A	Ingredients (aggregate, cementitious, water, admixtures)	—	Ingredient
B	Product Source (Mn/DOT Standard Abbreviation) ^b	—	Source
C	Total Moisture Factor (in decimals to 3 places)	—	MCFac
D	Absorption Factor (in decimals to 3 places)	—	AbsFac
E	Mn/DOT mix design oven dry (OD) weights, <i>lb/cu. yd [kg/cu. m]</i>	—	OD
F	Absorbed moisture in the aggregates, <i>lb/cu. yd [kg/cu. m]</i>	$(e \times d)$	Abs
G	Saturated surface dry (SSD) weights for aggregates, <i>lb/cu. yd [kg/cu. m]</i>	$(e + f)$	SSD
H	Free moisture, <i>lb/cu. yd [kg/cu. m]</i>	$(c - d) \times e$	Free Mst
I	Target weights for one cubic yard [cubic meter] of concrete, <i>lb/cu. yd [kg/cu. m]</i>	$(g + h)$	CY Targ [CM Targ]
J	Target batch weights, <i>lb [kg]</i>	$(cu. yd \times i)$ $[cu. m \times i]$	Target
K	Actual batch weights, <i>lb [kg]</i>	—	Actual
NOTE: Actual cubic yards [cubic meters] batched may vary due to differences in air content, weight tolerances, specific gravities of aggregates, and other variables.			

- (16) Total Water (Batch Water + Free Moisture) in pounds [kilograms].
- (17) Water available to add [(Mix Design Water) × (Target CY (CM)) – Total water] in gallons [liters].
- (18) Space to note the water adjustment information, including:
 - (18.1) Water in gallons [liters] added to truck at plant (filled in by producer, enter zero if no water is added).
 - (18.2) Water in gallons [liters] added to truck at the jobsite (filled in by producer or Engineer, enter zero if no water is added), and
 - (18.3) Total actual water in pounds [kilogram] (Total Water from Certificate of Compliance plus any additions).
- (19) The following information printed with enough room beside each item to allow the Engineer to record the test results:
 - (19.1) Air content,
 - (19.2) Air temperature,
 - (19.3) Concrete temperature,
 - (19.4) Slump,
 - (19.5) Cylinder number,
 - (19.6) Location or part of structure,
 - (19.7) Time discharge, and
 - (19.8) Signature of Inspector.
- (20) Location for the signature of the Mn/DOT Certified Plant 1 Technician representing the producer. The technician will review the first Certificate of Compliance for each mix type, each day, for accuracy and hand sign the Certificate of Compliance at a location designated for signature signifying agreement to the terms of this policy and to certify that the materials itemized in the shipment comply requirements of the contract.

F.3.h Decertification

If the Contractor provides concrete from a plant that cannot produce concrete, fails to perform testing, fails to report accurate results, or fails to complete the required documentation, the Engineer may reject the concrete as unacceptable in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

The Concrete Engineer, with coordination from the Engineer, may decertify the plant and halt production of concrete if the producer performs the following:

- (1) Procedural changes made after the completion of the Concrete Plant Contact Report and after starting the work that cause non-compliance with the program,
- (2) Continually produces concrete in non-compliance with this section,
- (3) Completely disregards the requirements of this section, and
- (4) Submits fraudulent test reports.

If decertifying the plant, the Concrete Engineer may perform the following:

- (1) Revoke plant certification.
- (2) Revoke technician certification for individuals involved,
- (3) Revoke bidding privileges as determined by the Construction Engineer, and
- (4) Criminal prosecution for fraud as determined by the Attorney General.

G Concrete Placement

Do not produce concrete earlier than 60 min before the National Weather Service official sunrise, unless the Engineer approves otherwise.

Place concrete after the Engineer inspects and approves the foundation preparations, forms and falsework erection, placement of reinforcement steel, materials, equipment condition, and cold weather protection.

Do not place concrete if portions of the base, subbase, or subgrade layer are frozen, or if the excessive moisture levels make the grade unstable. Maintain the surface temperature above freezing for forms, steel, and adjacent concrete that will come in contact with the poured concrete before concrete placement.

Protect the concrete from freezing.

Protect the concrete against damage from construction operations or traffic.

Assume full responsibility for the acceptable production, placement, finishing, and curing of all concrete under the conditions prevailing, regardless of the restrictions imposed. Provide any artificial lighting, rain or cold weather protection necessary at no additional cost to the Department. The Engineer may subject any defects in concrete or concrete surfaces resulting from weather conditions, inadequate lighting, or other causes to 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

G.1 Notice of Inspection

Notify the Engineer at least 24 h before beginning concrete production to allow the Engineer time to provide inspection forces needed for the work and to approve preparations for concrete placement. If the Contractor fails to provide 24 h notice, the Engineer may delay concrete placement in accordance with 1503, "Conformity with Contract Documents" and 1512, "Unacceptable and Unauthorized Work."

If the producer needs to change plants during placement, notify the Engineer and obtain approval before changing the plant.

G.2 Placement Temperatures

Do not place concrete when the air temperature at the point of placement is below 36 °F [2 °C] or is expected to fall below 36 °F [2 °C] within the following 24 h period unless approved cold-weather provisions are in place. Discontinue concrete placement if the air temperature falls below 36 °F [2 °C].

Maintain concrete at a temperature from 50 °F to 90 °F [10 °C to 30 °C] until placement.

G.3 Delivery Requirements

Place concrete into the work in accordance with the following:

- (1) Type 1 Concrete—within 90 min of batching, and
- (2) Type 3 Concrete—within 90 minutes of batching when all admixtures are added at the plant at the manufacturer's recommended dosage rates listed on the Approved Products list. If the haul time does not facilitate mixing and placing the concrete within 90 minutes, test the concrete in accordance with 2461.2.E.1.a.

The Contractor may transport Type 3 concrete in non-agitating equipment if the concrete is discharged within 45 min of batching.

Batch time starts when the batch plant or the transit mix truck adds the cement to the other batch materials.

G.4 Field Adjustments

Do not add additional mixing water once the concrete is 60 min old.

Mix the load a minimum of 5 minutes or 50 revolutions at mixing speed after addition of any admixture.

For concrete with slumps of greater than 1 inch (25 mm) do not make water adjustments after approximately 1 cubic yard (1 m^3) is discharged.

For concrete with slumps of 1 inch (25 mm) or less, the Engineer will allow water adjustments as necessary to facilitate placement.

The Engineer will test the concrete for compliance with 2461.3.G.6, "Consistency," and 2461.3.G.7, "Air Content," in accordance with the following:

- (1) If the first test taken by the Engineer passes, the Engineer will continue verification testing in accordance with the Schedule of Materials Control.
- (2) If the test taken by the Engineer fails, make adjustments and perform any quality control testing before the Engineer performs a final test. Acceptance or rejection of the truck is based on the Engineer's final test result.
- (3) The Engineer will test up to two additional trucks in accordance with items (1) and (2) above, and
- (4) If the concrete does not meet the specification after those three trucks, the Engineer will reduce their verification testing rate to once per truck for acceptance for the remainder of the pour.

G.5 Test Methods and Specimens

The Engineer will furnish molds based on the maximum size aggregate for the test specimens in accordance with the following:

- (1) 4 in × 8 in [100 mm × 200 mm] cylinder molds,
- (2) 6 in × 12 in [150 in × 300 mm] cylinder molds for maximum aggregate sizes greater than 1¼ in [31.5 mm], and
- (3) 6 in × 6 in × 20 in [150 in × 150 in × 500 mm] beam molds and use other beam mold sizes as approved by the Engineer.

Provide curing tanks of adequate size and number for curing all of the concrete test specimens in accordance with 2031.3.C, "Special Requirements." Supply the curing tanks with heaters to maintain a water temperature of 73 °F ± 3 °F [23 °C ± 2 °C].

If Contractor testing is required by the Contract, perform the following:

- (1) Determine the required testing rates in accordance with the Schedule of Materials Control,
- (2) Take samples after the first ¼ cu yd [cu. m] and before discharging the last ¼ cu. yd [cu. m] of the batch,
- (3) Perform concrete sampling and testing meeting the requirements of the Concrete Manual,
- (4) Measure slump and air content, and make strength specimens when placing the concrete,
- (5) Record field measurements, including strength specimen identifications on Mn/DOT Form 2448, *Weekly Concrete Report*, to provide to the Concrete Engineer.

The Engineer will transport the cylinders to the Department's Laboratory for testing.

G.5.a Standard Strength Cylinders

The Department will perform the following for standard strength cylinders:

- (1) Cast cylinders for testing at 28 days,
- (2) Mark cylinders for identification of the represented unit or section of concrete,
- (3) Cure the cylinders meeting the requirements of the Concrete Manual, and
- (4) Submit cylinders and a completed cylinder identification card to the Department's Laboratory.

The producer of precast units is responsible for casting standard strength cylinders.

G.5.b Control Strength Cylinders

The Engineer will use control cylinders to determine when the sequence of construction operations is dependent upon the rate of concrete strength development. The Engineer will cast control cylinders to determine when the concrete attains the required strength for all desired control limitations. The Contractor is responsible for any additional control cylinders beyond the requirements of 2461.3.G.5.b (1).

The Department will perform the following for control strength cylinders:

- (1) Cast up to three (3) control cylinders,
- (2) Cure the cylinders in the same location and under the same conditions as the concrete structure or unit involved meeting the requirements of the Concrete Manual,
- (3) Mark control cylinders for identification of the represented unit or section of concrete, and
- (4) Submit cylinders and a completed cylinder identification card to the Department's Laboratory.

If the Department is unavailable to test the control cylinders, the Contractor shall submit the control cylinders to an independent testing facility for testing or perform the testing on the control cylinders on a portable mechanical or hydraulic testing machine checked and calibrated with a standard proving ring as approved by the Engineer and in the presence of the Engineer.

The producer of precast units is responsible for casting control strength cylinders.

G.5.c Strength Specimens for Concrete Paving

Use flexural beams to determine strength or provide cylinders as allowed by the contract or approved by the Engineer.

Cast standard beams or cylinders for testing at 28 days.

Cast a sufficient number of control beams or cylinders to determine when the concrete attains the required strength for all desired control limitations.

Cure the standard beams or cylinders meeting the requirements of the Concrete Manual.

Cure the control beams or cylinders in the same location and under the same conditions as the concrete structure or unit involved meeting the requirements of the Concrete Manual.

The Engineer will test the flexural beams and record the results on Mn/DOT Form 2162, *Concrete Test Beam Data*.

If using cylinders, the Engineer will submit cylinders and a completed identification card to the Department's Laboratory.

G.6 Consistency

The Engineer will test the concrete for consistency using the slump test during the progress of the work. The Department may reject concrete batches with consistencies outside of the slump range in accordance with Table 2461-10. If any test shows the slump in excess of the upper limit of the slump range, the Engineer will reject the concrete represented by that test unless the Contractor makes adjustments to the concrete before use.

Adjust the slump within the allowable range to optimize both placement and finishing.

If not using a Department approved Type A water reducer at the manufacturer's recommended dosage rates listed on the Approved/Qualified Products List, meet the slump values for the slump range without water reducer in accordance with Table 2461-12.

If using a Department approved Type A water reducer at the manufacturer's recommended dosage rates listed on the Approved/Qualified Products List, meet the slump values for the slump range with water reducer in accordance with Table 2461-12.

Table 2461-12		
Slump Range Designation		
Slump Designation	Slump Range without Water Reducer, in [mm]	Slump Range with Water Reducer, in [mm]
1	½ – 1 [12 – 25]	½ – 1 [12 – 25]
2	1 – 2 [25 – 50]	1 – 3 [25 – 75]
3	1 – 3 [25 – 75]	1 – 4 [25 – 100]
4	2 – 4 [50 – 100]	2 – 5 [50 – 125]
5	2 – 5 [50 – 125]	2 – 6 [50 – 150]
6	3 – 6 [75 – 150]	3 – 7 [75 – 175]

Contact the Engineer if encountering unusual placement conditions that render the specified slump range unsuitable. The Department will provide mix composition modifications for Department designed mixes to provide the desired change in consistency while maintaining the other specified properties of the concrete mix. Do not add water solely to temporarily facilitate the placement of concrete.

G.6.a Concrete Placed by the Slip-Form Method

Place concrete that does not slough and is adequately consolidated at a slump value that optimizes placement for the designated mixture.

G.6.b Non-Conforming Material

Only place concrete meeting the slump requirements in the work. If the Contractor places concrete not meeting the slump requirements into the work, the Engineer will not accept non-conforming concrete at the contract unit price.

For concrete not meeting the required slump, the Engineer will make determinations regarding the disposition, payment, or removal. The Department will adjust the contract unit price for the contract item of the concrete in accordance with Tables 2461-13, 2461-14, 2461-15 and 2461-16. When there is not a separate contract unit price for *Structural Concrete* for an item of work or the concrete is a minor component of the contract unit price, the Department will reduce payment based on a concrete price of \$100.00 per cu. yd [\$130.00 per cu. m] or the Contractor-provided invoice amount for the concrete in question, whichever is less.

Table 2461-13 General Concrete*	
Outside of Slump Range	Adjusted Contract Unit Price
Below slump range*	The Department will pay 95 percent of the relevant contract unit price for materials placed as approved by the Engineer.
$\leq 1\frac{1}{2}$ in [40 mm] above slump range	The Department will pay 75 percent of the relevant contract unit price for materials placed as approved by the Engineer.
$1\frac{3}{4}$ in [45 mm] – $2\frac{1}{4}$ in [55 mm] above slump range	The Department will pay 50 percent of the relevant contract unit price for materials placed as approved by the Engineer.
$> 2\frac{1}{4}$ in [55 mm] above slump range	The Department will pay 25 percent of the relevant contract unit price for materials placed as approved by the Engineer.
* If the Contractor places piling or footing concrete below the slump range, the Department will deduct \$100 per cu. yd [\$130 per cu. m] or the Contractor-provided invoice amount to the relevant contract unit price of the concrete represented by the slump test, whichever is less. The Department will not reduce contract unit price for low slump concrete placed with the slip-form method as approved by the Engineer.	

Table 2461-14 Bridge Deck Concrete	
Outside of Slump Range	Adjusted Contract Unit Price
Below slump range	The Department will pay 95 percent of the relevant contract unit price for materials placed as approved by the Engineer.
$\leq 1\frac{1}{2}$ in [40 mm] above slump range	The Department will pay 75 percent of the relevant contract unit price for materials placed as approved by the Engineer.
$> 1\frac{1}{2}$ in [40 mm] above slump range	The Department will pay 25 percent of the relevant contract unit price for materials placed as approved by the Engineer.

Table 2461-15 Low Slump Bridge Deck Concrete From ½ in to 1 in [12 mm to 25 mm]	
Outside of Slump Range	Adjusted Contract Unit Price
Below slump range	No deduction for materials placed as approved by the Engineer.
≤ ½ in [12 mm] above slump range	The Department will pay 50 percent of the relevant contract unit price for materials placed as approved by the Engineer.
> ½ in – ¾ in [12 mm – 20 mm] above slump range	The Department will not pay for concrete placed but will allow the concrete to remain in place as approved by the Engineer.
> ¾ in [20 mm] above slump range	The Department will not pay for concrete. Provide additional testing as directed by the Engineer to determine if the concrete can remain in place or is subject to removal and replacement.

Table 2461-16 Low Slump Concrete — Patching From ½ in to 1 in [12 mm to 25 mm]	
Outside of Slump Range	Adjusted Contract Unit Price
Below slump range	No deduction for materials placed as approved by the Engineer
≤ ½ in [12 mm] above slump range	The Department will pay 75 percent of the relevant contract unit price for materials placed as approved by the Engineer.
≥ ¾ in [20 mm] above slump range	The Department will pay 25 percent of the relevant contract unit price for materials placed as approved by the Engineer.

G.7 Air Content

Maintain the air content of Type 3 general concrete at the specified target of 6.5 percent ±1.5 percent of the measured volume of the plastic concrete in accordance with 1503, “Conformity with Contract Documents.”

Make any adjustments immediately to maintain the desired air content.

Measure the air content at the point of placement but before consolidation.

G.7.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 non-conforming 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 item of the concrete in accordance with Table 2461-17. When there is not a separate contract unit price for *Structural Concrete* for an item of work or the concrete is a minor component of the contract unit price, the Department will reduce payment based on a concrete price of \$100.00 per cu. yd [\$130.00 per cu. m] or the Contractor-provided invoice amount for the concrete in question, whichever is less.

Table 2461-17 General Concrete (Target Air Content 6.5%)	
Air Content, %	Adjusted Contract Unit Price
> 10.0	The Department will pay 75 percent of the contract unit price for the concrete represented for material placed as approved by the Engineer.
>8.0 – 10.0	The Department will pay 95 percent of the contract unit price for the concrete represented for material placed as approved by the Engineer.
5.0 – 8.0	The Department will pay 100 percent of the contract unit price for the concrete represented, for material placed as approved by the Engineer.
>4.0 – <5.0	The Department will pay 75 percent of the contract unit price for the concrete represented for material placed as approved by the Engineer.
>3.5 – 4.0	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 approved epoxy penetrant sealer from the Approved/Qualified Products List.
≤ 3.5	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 in 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 approved epoxy penetrant sealer from the Approved/Qualified Products List.

G.8 Allowable Testing Tolerances

Allowable tolerances are based on the results from two different testers and two different pieces of equipment from the same sample. Perform the test within the allowable tolerances in accordance with Table 2461-18.

Table 2461-18 Allowable Testing Tolerances	
Test	Allowable Tolerance
Air content, % volume of concrete	1.0
Average slump:	
≤ 4 in [100 mm]	1.0 in [25 mm]
4 in – 6 in [100 mm – 150 mm]	1.5 in [38 mm]
≥ 6 in [150 mm]	2.0 in [50 mm]
Unit weight, per cu. ft [cu. m], calculated to an air-free basis	1.0 lb/cu. ft [16 kg/cu. m]
Compressive strength 3,000 psi – 8,000 psi [20.6 MPa – 55.2 MPa], average of 3 tests	500 psi [3.4 MPa]

2461.4 METHOD OF MEASUREMENT

The Engineer will measure fresh concrete produced as required by the contract by the theoretical volume.

The Engineer will deduct accountable waste from the concrete measurement.

The Engineer will measure concrete mixtures on the basis of the dimensions of the structure shown on the plans. If the plans do not include a contract item for concrete used in miscellaneous items, include the cost of the concrete with the relevant contract items.

2461.5 BASIS OF PAYMENT

The Department will include the cost of the Certified Ready-Mix Plant Program with other relevant contract items.

The contract cubic yard [cubic meter] price for *Concrete, Mix No.* ____ includes the cost of production, placement, finishing, curing, and protection of concrete.

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

Item No.:	Item:	Unit:
2461.501	Concrete, Mix No. ____	cubic yard [cubic meter]

MISCELLANEOUS CONSTRUCTION

2519 CELLULAR CONCRETE GROUT – CONTROLLED LOW STRENGTH MATERIAL (CLSM)

2519.1 DESCRIPTION

This work consists of pressure grouting the area and voids between the existing pipe culvert and the inserted liner pipe.

2519.2 MATERIALS

A Cement	3101
B Fly Ash	3115
C Fine Aggregate	3126
D (Blank)	
E Water	3906
F Admixtures	3113

2519.3 CONSTRUCTION REQUIREMENTS

A..... **Mix Design**

Submit a mix design on the Mn/DOT Concrete Mix Design Submittal Sheet to the Engineer for review and approval, in conjunction with the Concrete Engineer, at least 15 days before placing the grout. Design the CLSM in accordance with Table 2519-1 or Table 2519-2 and meeting the requirements of ASTM C 403.

A.1..... **CLSM Low Density**

Use the CLSM low density design when no water is present and no water intrudes during the setting process based on the following proportions per unit batch:

Table 2519-1 CLSM Low Density Design	
Materials	Proportions per unit batch and mix parameters
Portland cement	≥100 lb [45 kg]
Total cementitious (portland cement and Class C fly ash)	≥500 lb [300 kg]
Water/cementitious ratio	0.50
Pre-formed foam*	20 cu. ft [0.60 cu. m]
Grout (cast density)	30 lb ±3 lb per cu. ft [480 kg ±48 kg per cu. m]
Slump	10 in ± 1 in [250 mm ± 25 mm]
28-day compressive strength	75 psi – 400 psi [0.5 mPa – 2.8 mPa]
<p>* Provide foaming agent meeting the requirements of ASTM C 869 when tested in accordance with ASTM C 796. The Contractor may use other admixtures, if approved by the mix designer and the Engineer, in conjunction with the Concrete Engineer. Provide cementitious material from the Approved/Qualified Products List. The Engineer, in conjunction with the Concrete Engineer, will review the concrete mix design submittal and approve if the concrete mix design meets contract requirements. The Engineer will base final approval for payment on satisfactory field placement and performance.</p>	

A.2..... CLSM High Density

Use the CLSM high density design when it is not possible to dewater, keep water out of the annular space during grouting, or both, based on the following proportions per unit batch:

Table 2519-2 CLSM High Density Design	
Materials	Proportions per unit batch and mix parameters
Portland cement	≥150 lb [90 kg]
Total cementitious (portland cement and Class C fly ash)	≥500 lb [300 kg]
Fine aggregate	1,100 lb [650 kg]
Water/cementitious ratio	0.50
Pre-formed foam*	13.5 cu. ft [0.50 cu. m]
Grout (cast density)	70 lb ±3 lb per cu. ft [1,120 kg ±48 kg per cu. m]
Slump	10 in ±1 in [250 mm ±25 mm]
28-day compressive strength	75 psi – 400 psi [0.5 mPa – 2.8 mPa]
<p>* Provide foaming agent meeting the requirements of ASTM C 869 when tested in accordance with ASTM C 796. The Contractor may use other admixtures, if approved by the mix designer and the Engineer, in conjunction with the Concrete Engineer. Provide cementitious material from the Approved/Qualified Products List. The Engineer, in conjunction with the Concrete Engineer, will review the concrete mix design submittal and approve if the concrete mix design meets contract requirements. The Engineer will base final approval for payment on satisfactory field placement and performance.</p>	

B Grouting Procedure

Selected grouting pressures external to the liner pipe may collapse the liner pipe. Design a grouting procedure to fill voids between the existing culvert and the liner pipe, but will not collapse the liner pipe. Provide a pressure gauge to measure the grouting pressure and a method to measure the volume of injected grout. Submit a grouting plan to the Engineer for approval.

C Placement

Use grout to fill voids between the existing culvert and pipe liner, including breaks or holes in the existing culvert.

Secure the pipe liner to the invert of the existing culvert by fasteners or blocks, or construct multiple grout lifts to prevent the pipe liner from floating during the grouting operations.

After the grouting the liner to the in place culvert, encapsulate the remaining length of liner with Mix No. 3Y43 concrete at least 6 in [150 mm] thick.

Finish the inlet end with a 45° mitered fillet-transition between the in place culvert and the inside of the liner.

Use cylindrical wooden plugs, or other equivalent material approved by the Engineer, to plug grout holes. After the grout has set, remove the plugs and fill with concrete.

2519.4 METHOD OF MEASUREMENT

The Engineer will measure by the volume of grout injected into the void between the existing pipe culvert and the liner pipe. The Engineer will deduct accountable waste from the quantities measured for payment.

2519.5 BASIS OF PAYMENT

The contract cubic meter [cubic yard] price for CLSM includes the cost of dewatering, cement for securing the pipe liner to the existing culvert, and inlet bevel construction.

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

Item No.:	Item:	Unit:
2519.501	CLSM Low Density	cubic yard [cubic meter]
2519.502	CLSM High Density	cubic yard [cubic meter]

2520 LEAN MIX BACKFILL

2520.1 DESCRIPTION

This work consists of placing a lean cementitious, controlled-density backfill into utility and culvert trenches, or other excavations, where the use of conventional compacting equipment is impractical.

2520.2 MATERIALS

A Cement	3101
B Fly Ash	3115
C Fine Aggregate	3126
D Coarse Aggregate.....	3137

Provide coarse aggregate in accordance with 3137, "Coarse Aggregate for Portland Cement Concrete," except for 3137.2.D.2, "Coarse Aggregate for Bridge Superstructure," and 3137.2.D.3, "Coarse Aggregate for Concrete Pavement."

E **Water**
F **Admixtures** **3113**

2520.3 CONSTRUCTION REQUIREMENTS

A **Mix Design and Control**

Create lean mix backfill designs using the absolute volume relationships and basic mix proportions specified in this section (2520) for the control of cement, fly ash, water, and aggregate content and workability necessary for proper placement.

A.1 **Tentative Material Proportioning**

Proportion the material to obtain the flow-ability, workability, and consistency necessary for placement. Submit the source of materials to the Engineer. The Engineer, in conjunction with the Concrete Engineer, will provide a mix design based on the following table:

Table 2520-1 Lean Mix Backfill Mix Design	
Materials	Design per Unit Batch (1 cu. yd [1 cu. m])
Cement	125 lb [75 kg]
Fly ash	250 lb [150 kg]
Water	375 lb [225 kg]
Fine aggregate*	50%
Coarse aggregate*	50%
<p>* After adding the specified quantities of cement, fly ash, and water, provide the remaining volume consisting of fine aggregate and coarse aggregate. To increase flow-ability, the Contractor may replace no greater than 30 percent of the aggregate by volume with foam. Provide foam produced from a foaming agent meeting the requirements of ASTM C 869 when tested in accordance with ASTM C 796. When using a foaming agent, submit a mix design to the Engineer for review and approval, in conjunction with the Concrete Engineer, at least 15 days before placement. Base the mix design on the proportions specified in Table 2520-1, including the foaming agent per unit batch. The Contractor may use other admixtures as approved by the mix designer and by the Engineer, in conjunction with the Concrete Engineer. Supply cementitious material from the Approved/Qualified Products List. The Engineer, in conjunction with the Concrete Engineer, will review the concrete mix design submittal and, if the mix design meets contract requirements, will approve. The Engineer will base final approval for payment on satisfactory field placement and performance.</p> <p> Meeting the gradation range 6 as shown in 2461.2.F.3.d, "Coarse Aggregate (CA) Designation."</p>	

A.2 **Mix Requirements**

Table 2520-2 Lean Mix Backfill Design	
Testing	Requirements
Slump	10 in ±1 in [250 mm ±25 mm]
28-day unconfined compressive strength	75 psi [500 kPa] – 400 psi [2,750 kPa]

A.3 **Job Mix Proportions**

The Engineer will design the tentative job mix as specified in Table 2520-2.

A.4 **Mix Adjustments**

The Department may adjust the mix at any time to maintain the consistency and strengths specified in Table 2520-2.

B **Production Controls**

Provide production controls in accordance with 2461.3.C, "Handling and Storing Materials," and 2461.3.G, "Concrete Placement," except replace the word "concrete" with "lean mix."

C.....Batching and Mixing Requirements

C.1.....Proportioning Methods

Proportion lean mix batch materials by weight [mass]. The Contractor may proportion lean mix batch material by volume as approved by the Engineer in writing.

C.2..... Other Batching and Mixing Requirements

Batch and mix lean mix materials in accordance with 2461, except replace the word, “concrete” with “lean mix.”

D..... Ready-Mixed Lean Mix Backfill

Provide ready-mixed lean mix backfill in accordance with 2461, “Structural Concrete,” except replace the word “concrete” with “lean mix.”

E..... Construction Requirements

Plug openings below the level of the desired backfill that would allow the mix to escape. Place the lean mix so that it flows around and beneath footings, foundations, walls, pipes, or other structures that it was designed to support. The Department will not require compaction or mechanical vibration when lean mix backfill is placed as approved by the Engineer. Vent or eliminate air pockets that water would normally fill to preclude voids remaining in the completed backfill.

E.1 Curing and Protection

Maintain the air in contact with lean mix backfill surfaces at temperatures above freezing for at least 72 h.

The Department will not require additional curing after the evaporation of the substantial water gain on the surface.

2520.4 METHOD OF MEASUREMENT

If the contract specifies *Lean Mix Backfill* as a contract item, the Engineer will measure lean mix backfill as the computed, theoretical volume based on the weight of the individual batch ingredients. The Engineer will deduct the volume of accountable waste from the measurement of lean mix backfill.

2520.5 BASIS OF PAYMENT

The Department will include the cost of lean mix backfill and common backfill with other relevant contract items unless otherwise shown on the plans.

The contract cubic yard [cubic meter] price for *Lean Mix Backfill* includes the cost of providing the lean mix backfill and the cost of forming, plugging, placing, venting, and protecting.

Item No.:	Item:	Unit:
2520.501	Lean Mix Backfill	cubic yard [cubic meter]

2521 WALKS

2521.1 DESCRIPTION

This work consists of constructing concrete or bituminous walks.

2521.2 MATERIALS

A..... Concrete.....2461

A.1..... Concrete Walk Mix No. 3A32

A.2..... Concrete Walk, Exposed Aggregate FinishMix No. 3A36EX

B	Preformed Joint Filler	3702
C	Bituminous	2360
C.1.....	Bituminous Walk	Mix No. SPWEB230B
D.....	Curing Materials	
D.1.....	Burlap Curing Blankets	3751
D.2.....	Poly-Alpha Methylstyrene (AMS) Membrane Curing Compound	3754
D.3.....	Linseed Oil Membrane Curing Compound.....	3755
D.4.....	Plastic Curing Blankets.....	3756
E	Granular Materials.....	3149

2521.3 CONSTRUCTION REQUIREMENTS

A..... Foundation Preparations

Excavate, shape, and compact the foundation to a firm, uniform bearing surface to the dimensions and grade as shown on the plans and in accordance with 2105, "Excavation and Embankment," 2112, "Subgrade Preparation," and 2211, "Aggregate Base."

B..... Sawing Concrete Walk

Saw existing concrete walk to produce a neat line for the new work.

C..... Forms

Provide forms made of non-reactive metal or wood, or other material in accordance with 1805, "Method and Equipment," capable of maintaining the concrete until the concrete can retain the molded shape. Provide forms with a height at least equal to the walk thickness of the formed concrete shown on the plans. Support the forms on the foundation to maintain the line and grade shown on the plans.

Before placing the concrete, coat the contact surfaces of the forms with an approved form treating material in accordance with 3902, "Form Coating Material."

D..... Placing and Finishing Concrete

Wet the foundation and forms before placing the concrete.

Prevent segregation of the concrete during placement. Consolidate the concrete to fill voids using hand tamping or internal vibrating. Strike-off the concrete to the grade shown on the plans, and float the surface smooth. After the water sheen disappears, edge the joints and lightly brush the surface to a uniform texture.

The Engineer will use a 10 ft [3 m] straight edge to measure the surface. The Department considers deviations in the surface greater than $\frac{3}{16}$ in [5 mm] and deviations in formed concrete greater than $\frac{1}{2}$ in [13 mm] from the required location as unacceptable work. Remove and replace unacceptable work as directed by the Engineer.

Leave forms in place for at least 12 h after placing the concrete unless otherwise approved by the Engineer.

D.1..... Exposed Aggregate Finish

Provide concrete Mix No. 3A36EX with multi-colored rounded stone, modified for exposed aggregate construction.

Use surface retardation, meeting the Type B requirements in 3113, "Admixtures for Concrete," to produce a medium to deep exposure on the aggregate finish making the aggregate the dominant surface feature. Do not embed or top seed the aggregate.

Apply retardant coating immediately after completion of the concrete surface screeding, edging, and jointing. Apply retardant as recommended by the manufacturer to produce a ¼ in ± ⅛ in [6 mm ± 2 mm] etch of mortar removal after final concrete set.

Use pressurized water to remove surface mortar. Do not loosen individual aggregate particles with the pressurized water.

After the Engineer approves the exposed aggregate finish, apply a 10 percent muriatic acid solution to the exposed aggregate surfaces. Allow the acid solution to interact with the exposed aggregate surface for 5 min to 10 min before flushing the surface with water.

Cover the concrete with white polyethylene sheeting to continue curing. Before applying sealer, remove staining or streaking from the exposed aggregate surface resulting from the moist curing.

Seal the exposed aggregate finish with two coats of a clear acrylic based compound with at least 18 percent solids meeting the requirements of ASTM C 309.

D.2.....Joint Construction

Divide the walk into square panels of uniform size no greater than 36 sq. ft [3 sq. m] and outlined with contraction or expansion joints as shown on the plans.

Provide vertical and straight joints parallel with or at right angles to the walk centerline. Align the joints with joints in adjoining work unless isolated by a ½ in [13 mm] preformed joint filler.

The Contractor may form or saw the joints in walking surfaces as approved by the Engineer. If forming the joints, round joints within the walking surface with a ¼ in [6 mm] radius grooving tool and round edges of the walk with an edging tool having a radius no greater than ½ in [13 mm].

Extend contraction joints to a depth of at least 30 percent of the walk thickness. If saw cutting, provide ⅛ in [3 mm] wide contraction joints.

Provide joint filler in accordance with 3702, "Preformed Joint Fillers," that is ½ in [13 mm] wide and equal in depth to the full thickness of the walk.

Modify joint construction if a fixed object or structure extends through the walk, as directed by the Engineer. Place preformed joint filler material ½ in [13 mm] thick adjacent to fixed objects to separate the object from the abutting concrete edges.

.....
E.....Concrete Curing and Protection

After completing final finishing operations, cure all exposed concrete surfaces. Use one 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 2521.3.E.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 as soon as practical without marring the surface in accordance with 2521.3.E.1.b, "Curing Blanket Method."

Failure to comply with these provisions will result in the Engineer applying a monetary deduction in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work." If the contract does not contain a separate contract item for *Structural Concrete*, the Department will apply a monetary deduction of \$50.00 per cubic yard (\$65.00 per cubic meter) or 50 percent of the Contractor-provided invoice amount for the concrete in question, whichever is less.

Whenever weather conditions are such as to cause unusual or adverse placing and finishing conditions, 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.

E.1 Curing Methods

E.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 with an approved airless spraying machine in accordance with the following:

- (1) At a rate of 1 gal per 150 sq. ft (1 L per 4 m²) of surface curing area.
- (2) Apply homogeneously to provide a uniform solid white opaque coverage on all exposed concrete surfaces (equal to a white sheet of typing paper). Some Mn/DOT approved curing compounds may have a base color (i.e. yellow) that cannot comply with the above requirement. In this case, provide a uniform solid opaque consistency meeting the intent of the above requirement.
- (3) If the curing compound is damaged during the curing period, immediately repair the damaged area by re-spraying.

The Engineer will approve the airless spraying machine for use if it is equipped 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.

If the Engineer determines that the initial or corrective spraying may result in unsatisfactory curing, the Engineer may require the Contractor to use the blanket curing method, at no additional cost to the Department.

E.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.

E.2Protection 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 concrete. Should any damage result, the Engineer will suspend operations until the Contractor takes corrective action, and may subject the rain-damaged concrete to 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

E.3Protection Against Cold Weather

If the national weather service forecast for the construction area predicts air temperatures of 36 °F [1 °C] or less within the next 24 h and the Contractor wishes to place concrete, submit a cold weather protection plans.

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

E.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.

FBituminous

Place the bituminous mixture in accordance with 2360.

G.....Backfill Construction

Protect newly placed concrete from damage by adjacent vibratory or backfilling operations for a minimum of 24 hours. Perform vibratory operations and backfilling 72 h after placing the concrete or after the concrete reaches a compressive strength of at least 3,000 psi [20.7 Mpa]. The Engineer will cast, cure, and test the concrete control specimens in accordance with 2461.3.G.5.b, "Control Strength Cylinders." If damage results from any of these operations, the Engineer will suspend all operations until the Contractor takes corrective action and obtains the Engineer's approval of a new method. The Engineer may require removal and replacement of the 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 and walk behind vibratory plate compactors 24 h after placing the concrete, and other equipment as approved by the Engineer, in conjunction with the Concrete Engineer.

As soon as possible after the curing is complete and without subjecting the concrete work to damaging stresses, perform the backfill or embankment construction to the elevations shown on the plans. Use suitable grading materials from the excavation for backfill material in accordance with 2105, "Excavation and Embankment," unless otherwise required by the contract. Place and compact the backfill material in accordance with 2105, "Excavation and Embankment."

Dispose of surplus excavated materials in accordance with 2105, "Excavation and Embankment."

2521.4 METHOD OF MEASUREMENT

The Engineer will measure each uniform thickness item separately by top surface area.

2521.5 BASIS OF PAYMENT

The Contract Unit Price for concrete or bituminous construction includes furnishing the materials and placement of the Work to the lines and grade of the Plan as specified.

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

Item No.:	Item:	Unit:
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Item No.:	Item:	Unit:
2521.501	Concrete Walk ___ in [___ mm]	square foot [square meter]
2521.511	Bituminous Walk ___ in [___ mm]	square foot [square meter]

2531 CONCRETE CURBING

2531.1 DESCRIPTION

This work consists of constructing cast-in-place concrete curbs, curb and gutter, medians, driveway pavement, pedestrian ramps, and other similar traffic delineation or service items.

2531.2 MATERIALS

A..... Concrete.....2461

For each method of placement, use the following mix designations:

A.1..... Manual Placement Mix No. 3A32

A.2..... Slip-form Placement Mix No. 3A22

B..... Reinforcement Bars3301

C..... Steel Fabric.....3303

D..... Preformed Joint Filler3702

E..... Curing Materials

E.1..... Burlap Curing Blankets3751

E.2..... Poly-Alpha Methylstyrene (AMS) Membrane Curing Compound3754

E.3..... Linseed Oil Membrane Curing Compound.....3755

E.4..... Plastic Curing Blankets3756

F..... Granular Materials.....3149

2531.3 CONSTRUCTION REQUIREMENTS

A..... Foundation Preparations

Excavate, shape, and compact the foundation to a firm, uniform bearing surface that conforms to the dimensions and grade shown on the plans and in accordance with 2105, "Excavation and Embankment," 2112, "Subgrade Preparation," and 2211, "Aggregate Base."

B..... Forms

Provide forms, made of metal, wood, or other materials in accordance with 1805, "Methods and Equipment," capable of maintaining the concrete until the concrete can retain its molded shape. Provide side forms with a depth at least equal to the edge thickness of the concrete being formed. Support the forms on the foundation and restrain at the line and grade as shown on the plans.

For curves with a radius no greater than 100 ft [30 m], use flexible or curved forms approved by the Engineer.

Before placing concrete, coat the contact surfaces of forms with an approved form treating material in accordance with 3902, "Form Coating Material."

C..... Placing and Finishing Concrete

Immediately before placing the concrete wet the foundation and the forms.

Place the concrete in a manner that will prevent segregation. Consolidate the concrete to fill voids using hand tamping or internal vibrating. Strike-off the concrete to the grade shown on the plans, and float the surface smooth.

After the water sheen has disappeared, round joints and edges to the radii shown on the plans. Lightly brush concrete surfaces exposed to view to a uniform texture.

Keep side forms in place for at least 12 h after casting the concrete.

D.....Slipform Machine Placement

Instead of using fixed forms, the Contractor may use a slipform machine capable of placing and forming concrete to the dimensions, quality, workmanship, and appearance as required by the contract. Hand finish the surface to the finish and texture as required by the contract.

E.....Joint Construction

Place transverse expansion joints, filled with ½ in [13 mm] preformed joint filler material, at the ends of curved sections and at the ends of the curved portions of entrance and street returns. Place longitudinal expansion joints as shown on the plans. Place expansion joints with filler material at locations where the concrete surrounds or adjoins an existing fixed object, such as a fire hydrant, building foundation, or other rigid structure.

Provide contraction joints at the following intervals, except as otherwise shown on the plans:

- (1) Adjacent to bituminous mainline, every 10 ft [3.0 m],
- (2) Adjacent to concrete mainline, match the adjacent concrete pavement joints, and
- (3) In solid median construction, every 10 ft [3.0 m].

Form or saw the contraction joints, as approved by the Engineer, to a depth of at least 2 in [50 mm] from exposed surfaces.

Construct joints perpendicular to the subgrade. Align joints with joints in adjoining work unless a ½ in [13 mm] preformed joint filler isolates the work. Place transverse joints at right angles to the longitudinal axis of the work, unless otherwise required by the contract.

Use an edging tool with a radius no greater than ½ in [13 mm] to round edges of longitudinal construction joints between a concrete median or gutter section and a concrete pavement.

Do not saw or seal longitudinal construction joints between a concrete median and concrete pavement, or between a gutter section and concrete pavement.

F.....Metal Reinforcement

Provide and place metal reinforcement as shown on the plans and in accordance with 2472, "Metal Reinforcement."

G.....Concrete Curing and Protection

After completing final finishing operations, cure all exposed concrete surfaces. Use one 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 min of concrete placement or once the bleed water has dissipated, unless the Engineer directs otherwise in accordance with 2531.3.G.1.a, "Membrane Curing Method." Place the membrane curing compound on the edges within 30 min 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 as soon as practical without marring the surface in accordance with 2531.3.G.1.b, "Curing Blanket Method."

Failure to comply with these provisions will result in the Engineer applying a monetary deduction in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work." If the contract does not contain a separate contract item for *Structural Concrete*, the Department will apply a monetary deduction of \$50.00 per cu. yd [\$65.00 per cu. m] or 50 percent of the Contractor-provided invoice amount for the concrete in question, whichever is less.

Whenever weather conditions are such as to cause unusual or adverse placing and finishing conditions, 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.

G.1..... Curing Methods

G.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 with an approved airless spraying machine in accordance with the following:

- (1) At a rate of 1 gal per 150 sq. ft [1 L per 4 m²] of surface curing area.
- (2) Apply homogeneously to provide a uniform solid white opaque coverage on all exposed concrete surfaces (equal to a white sheet of typing paper). Some Mn/DOT approved curing compounds may have a base color (i.e. yellow) that cannot comply with the above requirement. In this case, provide a uniform solid opaque consistency meeting the intent of the above requirement.
- (3) If the curing compound is damaged during the curing period, immediately repair the damaged area by re-spraying.

The Engineer will approve the airless spraying machine for use if it is equipped 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.

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.

G.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.

G.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 concrete. Should any damage result, the Engineer will suspend operations until the Contractor takes corrective action, and may subject the rain-damaged concrete to 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

G.3..... Protection Against Cold Weather

If the national weather service forecast for the construction area predicts air temperatures of 36 °F [1 °C] or less within the next 24 h and the Contractor wishes to place concrete, 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 the Contractor takes corrective action, and may subject the damaged concrete to 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

G.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.

H.....Backfill Construction

Protect newly placed concrete from damage by adjacent vibratory or backfilling operations for a minimum of 24 hours. Perform vibratory operations and backfilling at least 72 h after placing the concrete or after the concrete reaches a compressive strength of at least 3,000 psi [20.7 Mpa]. The Engineer will cast, cure, and test the concrete control specimens in accordance with 2461.3.G.5.b, "Control Strength Cylinders." If damage results from any of these operations, the Engineer will suspend all operations until the Contractor takes corrective action and obtains the Engineer's approval of a new method. The Engineer may require removal and replacement of the 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 and walk behind vibratory plate compactors 24 h after placing the concrete, and other equipment as approved by the Engineer, in conjunction with the Concrete Engineer.

As soon as possible after the curing is complete and without subjecting the concrete work to damaging stresses, perform the backfill or embankment construction to the elevations as shown on the plans. Use suitable grading materials from the excavations in accordance with 2105, "Excavation and Embankment," unless the contract requires otherwise. Place and compact the backfill material in accordance 2105, "Excavation and Embankment."

Dispose of surplus excavated materials in accordance with 2105, "Excavation and Embankment."

I.....Workmanship and Finish

Ensure the surface contour and texture of the completed concrete work is uniform and meets the lines and grades as shown on the plans. Finish the flow line surface of gutters to eliminate low spots and avoid entrapment of water.

The Engineer will use a 10 ft [3 m] straightedge to measure the surface. The Engineer will consider concrete work with deviations $\frac{3}{8}$ in [10 mm] or greater in any 10 ft [3 m] length of finish curb and gutter, either horizontal or vertical, as unacceptable work. Remove and replace unacceptable work as directed by the Engineer.

If the Engineer does not direct the removal and replacement of unacceptable work, the Engineer will reduce the contract unit price for the unacceptable concrete work in accordance with the following:

- (1) For deviations from $\frac{3}{8}$ in to $\frac{9}{16}$ in [10 mm to 14 mm], payment at 75 percent of the contract unit price; and
- (2) For deviations greater than $\frac{9}{16}$ in [14 mm], payment at 50 percent of the contract unit price.

2531.4 METHOD OF MEASUREMENT

The Engineer will not make deductions for castings or minor fixtures in the work.

A.....Length

For curbs and curb and gutter, including the curb returns, the Engineer will measure the length along the face of the curb at the gutter line. In the case of transitions from one size or design to another, the Engineer will measure the entire transition for payment under the item with the higher contract unit price.

For solid medians and other construction with uniform widths and symmetrical cross sections, the Engineer will measure the length along the center of the longitudinal axis. Unless a variance from the basic design results in an increased cross-sectional area, the Engineer will include the measurements of short sections of modified design, such as tapers and depressions, for payment with the basic design if the contract does not contain a separate pay item for the modified design.

B Area

For area measurements, the Engineer will measure the staked length and the extreme width between the outside faces as shown on the plans. The Engineer will disregard variations in concrete thickness caused by integral construction. The Engineer will separately measure driveway pavement of each specified thickness.

C Pedestrian Curb Ramps

The Engineer will measure pedestrian curb ramps by the number of pedestrian curb ramps constructed.

The Engineer will measure the surface area of each type of pedestrian curb ramps using the outer most edge of the concrete walk, curb, or curb and gutter.

2531.5 BASIS OF PAYMENT

The Contract Unit Price for concrete construction includes furnishing the materials and placement of the Work to the lines and grade on the plans as specified.

The Department will pay for concrete curbing, median, and driveway construction on the basis of the following schedule:

Item No.	Item:	Unit:
2531.501	Concrete Curb and Gutter, Design	linear foot [meter]
2531.502	Concrete Curb, Design	linear foot [meter]
2531.503	Concrete Median	square yard [square meter]
2531.505	Concrete Median	linear foot [meter]
2531.507	___ in [mm] Concrete Driveway Pavement	square yard [square meter]
2531.530	Concrete Entrance Nose, Design 7107	each
2531.531	Concrete Entrance Nose, Design 7108	each
2531.532	Pedestrian Curb Ramp (Type ___)	each
2531.533	Pedestrian Curb Ramp (Type ___)	square yard [square meter]

2533 CONCRETE MEDIAN BARRIERS

2533.1 DESCRIPTION

This work consists of constructing or reconstructing cast-in-place or precast median barriers for traffic lane separation.

2533.2 MATERIALS

A Concrete.....2461

A.1 Fixed Form Cast-In-Place Mix No. 3Y32

A.2 Slipform Placement Mix No. 3Y12 or 3Y16

A.3 Precast.....

Mix No.

B	Reinforcement Bars	3301
C	Dowel Bars	3302
D	Precast Concrete Median Barrier	3630
E	Curing Materials	
E.1	Burlap Curing Blanket	3751
E.2	Poly-Alpha Methylstyrene (AMS) Membrane Curing Compound	3754
E.3	Linseed Oil Membrane Curing Compound	3755
E.4	Plastic Curing Blankets	3756
F	Granular Materials	3149

2533.3 CONSTRUCTION REQUIREMENTS

A

General
The Contractor may combine cast-in-place and precast concrete construction as approved by the Engineer if the plans do not specify the construction type and if the construction maintains structural strength, continuity, or both.

Use a tongue and groove joint with tied dowels or reinforcement bars or other positive connection to interlock the connection between a new median barrier and an existing barrier to prevent movement, as approved by the Engineer.

Excavate, shape, and compact the foundation to a firm, uniform bearing surface and grade as shown on the plans and in accordance with 2105, "Excavation and Embankment," 2112, "Subgrade Preparation," and 2211, "Aggregate Base."

B

Cast-In-Place Fixed Form Construction
Provide forms made of non-reactive metal, wood, or other material in accordance with 1805, "Methods and Equipment," capable of maintaining the concrete until the concrete can retain the molded shape. Provide side forms with a depth at least equal to the edge thickness of the formed concrete. Support the forms on the foundation to maintain the concrete line and grade as shown on the plans. Before placing the forms, coat the contact surfaces of the forms with an approved form treating material in accordance with 3902, "Form Coating Material."

Wet the foundation and forms immediately before placing the concrete.

Prevent segregation during placement of concrete. Use internal vibration to consolidate the concrete and fill voids. Strike-off the concrete to the grade as shown on the plans and float the surface smooth. When the concrete can retain the molded shape, remove the forms from the roadway face of the median barrier. Keep non-roadway face forms in place for at least 12 h after casting the concrete.

Round concrete edges to the radii as shown on the plans after removing the roadway face forms.

C..... Cast-In-Place Slipform Construction

Rather than using fixed forms, the Contractor may use a slipform machine capable of placing and forming concrete to the dimensions, quality, workmanship, and appearance as required by the contract. Hand finish the concrete surface to the finish and texture as required by the contract.

D..... Surface Finishes

D.1..... Cast-In-Place

Apply an ordinary surface finish in accordance with 2401.3.F, "Finish of Concrete," on cast-in-place concrete median barriers.

D.2..... Precast

Place the barrier in its final location. Obtain the Engineer's approval of the surface condition of the barrier before applying the special surface finish treatment on precast concrete median barrier in accordance with 2401.3.F, "Finish of Concrete."

.....
E..... Concrete Curing and Protection

When the contract requires additional surface finishing (i.e. painting), cure in accordance with 2533.3.E.1.b. "Curing Blanket Method."

After completing final finishing operations, cure all exposed concrete surfaces. Use one 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 min of concrete placement or once the bleed water has dissipated, unless otherwise directed by the Engineer in accordance with 2533.3.E.1.a, "Membrane Curing Method." Place the membrane curing compound on the edges within 30 min 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 as soon as practical without marring the surface in accordance with 2533.3.E.1.b, "Curing Blanket Method."

Failure to comply with these provisions will result in the Engineer applying a monetary deduction in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work." If the contract does not contain a separate contract item for *Structural Concrete*, the Department will apply a monetary deduction of \$50.00 per cubic yard [\$65.00 per cubic meter] or 50 percent of the Contractor-provided invoice amount for the concrete in question, whichever is less.

Whenever weather conditions are such as to cause unusual or adverse placing and finishing conditions, 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.

E.1 Curing Methods

E.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 with an approved airless spraying machine in accordance with the following:

- (1) At a rate of 1 gal per 150 sq. ft [1 L per 4 m²] of surface curing area.
- (2) Apply homogeneously to provide a uniform solid white opaque coverage on all exposed concrete surfaces (equal to a white sheet of typing paper). Some Mn/DOT approved curing compounds may have a base color (i.e. yellow) that cannot comply with the above requirement. In this case, provide a uniform solid opaque consistency meeting the intent of the above requirement.
- (3) If the curing compound is damaged during the curing period, immediately repair the damaged area by re-spraying.

The Engineer will approve the airless spraying machine for use if it is equipped 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.

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.

E.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.

E.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 concrete. Should any damage result, the Engineer will suspend operations until the Contractor takes corrective action, and may subject the rain-damaged concrete to 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

E.3 Protection Against Cold Weather

If the national weather service forecast for the construction area predicts air temperatures of 36 °F [1 °C] or less within the next 24 h and the Contractor wishes to place concrete, 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 the Contractor takes corrective action, and may subject the damaged concrete to 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

E.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.

F Workmanship and Finish

The Engineer will use a 10 ft [3 m] straight edge to measure the surface. The Engineer will consider horizontal or vertical irregularities of $\frac{5}{16}$ in [8 mm] or greater in the surface of any 10 ft [3 m] length of the finished concrete median barrier as unacceptable work. Remove and replace extensive (more than 10 percent of the median barrier length) with deviations greater than $\frac{1}{2}$ in [13 mm]. Remove and replace unacceptable work as directed by the Engineer.

If the Engineer does not direct removal of unacceptable work, the Contractor may leave the work in place and the Department will make the following adjustments to the contract unit prices:

- (1) For deviations from $\frac{5}{16}$ in [8 mm] to $\frac{1}{2}$ in [13 mm], 75 percent of the contract unit price, and
- (2) For minor areas (equal to or less than 10 percent of the median barrier length) with deviations greater than $\frac{1}{2}$ in [13 mm], 50 percent of the contract unit price.

2533.4 METHOD OF MEASUREMENT

The Engineer will measure the concrete median barrier on the top of the barrier, along the centerline for Type A barriers, and 3 in [75 mm] behind the front face for Type AA barriers. The Engineer will measure transitions, and special and modified barriers by the length on the top of the barrier and 3 in [75 mm] behind the front face.

The Engineer will separately measure each type of concrete median barrier.

2533.5 BASIS OF PAYMENT

The Contract Unit Price for concrete median barrier construction includes furnishing the materials, placement of the Work to the lines and grade on the plans, and surface finish as specified.

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

Item No.:	Item:	Unit:
2533.501	Concrete Median Barrier, Design ___* Type ___	linear foot [meter]
2533.506	Concrete Median Barrier and Glare Screen, Design ___* Type ___	linear foot [meter]
2533.507	Portable Precast Concrete Barrier, Design ___*	linear foot [meter]
2533.508	Relocate Portable Precast Concrete Barrier, Design ___*	linear foot [meter]
*	Current standard plate	
	Type A, Type AA, Type AL, Transition, A Step, or AA Step	

2535 BITUMINOUS CURB

2535.1 DESCRIPTION

This work consists of constructing a curb using bituminous material.

2535.2 MATERIALS

Use the same type of bituminous mixture for the curb as the type specified for the pavement wearing course in accordance with 2360, "Plant Mixed Asphalt Pavement."

2535.3 CONSTRUCTION

A..... Tack

Apply a tack coat as specified in 2357, "Bituminous Tack Coat," on the pavement wearing course beneath the curb.

B..... Equipment

Place bituminous curb using an automatic curb machine that shapes and compacts the mixture to the profile shown on Standard Plate 7065. The Contractor may only manually place the bituminous curb in locations unreachable by the machine, if approved by the Engineer.

C.....Finishing

Place curb uniform in appearance and texture, and true to line and grade.

2535.4 METHOD OF MEASUREMENT

The Engineer will measure bituminous curb by length along the face of the curb at gutter line.

2535.5 BASIS OF PAYMENT

The contract linear foot [meter] price for *Bituminous Curb* includes the cost of construction and providing the bituminous mixture.

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

Item No.:	Item:	Unit:
2535.501	Bituminous Curb	linear foot [meter]

CEMENTING MATERIALS

3101 PORTLAND CEMENT

3101.1 SCOPE

Provide portland cement material for use in concrete applications.

3101.2 REQUIREMENTS

Supply portland cement from the certified source listed on the Approved/Qualified Products List, meeting the requirements of AASHTO M 85, and in accordance with the following modifications:

- (1) If using low alkali cement as required by the contract, do not allow greater than 0.60 percent total alkalis in the portland cement ($\text{Na}_2\text{O} + 0.658 \text{K}_2\text{O}$) or greater than 5.0 lb per cu. yd [3.0 kg per cu. m] total alkalis in the cementitious material.
- (2) Include the following standardized cement certification statement with delivery invoices: "(insert company name) certifies that the cement produced at (insert plant and location) conforms to AASHTO M 85 and Mn/DOT Specification 3101 for Type (insert type) cement."

Do not change the source or color, or both, of cement on a project without the written approval of the Engineer.

3101.3 SAMPLING AND TESTING

Provide samples for testing meeting the requirements of the Schedule of Materials Control. Measure fineness in accordance with the air permeability test in AASHTO M 85.

3102 GROUND GRANULATED BLAST-FURNACE SLAG

3102.1 SCOPE

Provide ground granulated blast-furnace slag material for use in concrete applications.

3102.2 REQUIREMENTS

Provide slag from the certified source listed on the Approved/Qualified Products List, meeting the requirements of AASHTO M 302, and the following modifications:

- (1) Provide Grade 100 or Grade 120 slag classifications, and
- (2) Include the following standardized slag certification statement with delivery invoices: "(insert company name) certifies that the slag produced at (insert plant and location) conforms to AASHTO M 302 and Mn/DOT Specification 3102 for grade (insert grade) slag."

Do not change the source or color, or both, of slag on a project without the written approval of the Engineer.

3102.3 SAMPLING AND TESTING

Provide samples for testing meeting the requirements of the Schedule of Materials Control.

3103 BLENDED HYDRAULIC CEMENT

3103.1 SCOPE

Provide blended hydraulic cement material for use in concrete applications.

3103.2 REQUIREMENTS

Provide blended hydraulic cement from the certified source listed on the Approved/Qualified Products List, meeting the requirements of AASHTO M 240, Type IS or Type IP, or Type IL and the following modifications:

- (1) Fly ash constituent of the blended cement no greater than 25 percent,
- (2) Slag constituent of blended cement no greater than 35 percent,
- (3) Silica fume constituent of blended cement no greater than 7 percent,
- (4) Total alkalis in the blended cement no greater than 5.0 lb per cu. yd [3.0 kg per cu. m], and
- (5) Include the following standardized cement certification statement with delivery invoices: “(insert company name) certifies that the cement produced at (insert plant and location) conforms to AASHTO M 240 and Mn/DOT Specification 3103 for type (insert type) cement.”

Do not change the source or color, or both, of cement on a project without the written approval of the Engineer.

3103.3 SAMPLING AND TESTING

Provide samples for testing meeting the requirements of the Schedule of Materials Control.

3105 BAGGED PORTLAND CEMENT CONCRETE PATCHING MIX GRADE 3U18

3105.1 SCOPE

Provide dry, bagged concrete patching mix for repairing portland cement concrete pavement.

3105.2 REQUIREMENTS

A..... Materials

Provide materials for patching mix meeting the following requirements:

A.1..... Cement.....3101

A.2..... Fine Aggregate.....3126

A.3..... Coarse Aggregate.....3137

Provide materials with the patching mix to make concrete meeting the following requirements:

A.4..... Water.....

3906

A.5..... Admixtures.....3113

B..... Gradation

Blend the coarse and fine aggregate at a 50-50 ratio by volume and meet the following gradation requirements:

Table 3105-1 3U18 Gradation Requirements	
Sieve Size	Percent Passing
3/8 in [9.5 mm]	100
No. 4 [4.75 mm]	80 – 100
No. 8 [2.3 mm]	40 – 80
No. 16 [1.18 mm]	25 – 50
No. 30 [600 μm]	15 – 35
No. 50 [300 μm]	0 – 18
No. 100 [150 μm]	0 – 8
No. 200 [75 μm]	≤ 2.3

C..... Mix Proportions

Proportion the mix in accordance with Table 3105-2 per 75 lb [34.1 kg] bag of dry mix. Proportion other bag sizes of 3U18 mix in accordance with Table 3105-2.

Table 3105-2 Mix Proportions	
Material	Weight, lb [kg]
Type I Cement	17.8 [8.1]
Coarse Aggregate	28.3 [12.9]
Fine Aggregate	28.9 [13.1]

D.....Blending

Provide a blending device meeting the following characteristics and requirements:

- (1) Capable of producing the required mix proportions within ± 2 percent,
- (2) Contains a proportioning device equipped with a warning device to indicate when the system is out-of-tolerance,
- (3) Capable of stopping the flow of cement to allow sampling of the blended coarse and fine aggregate, and
- (4) Designed to allow cement and aggregate to run out separately for checking material weights and ensuring that the blending proportions meet mix requirements.

Before blending with the cement, dry the coarse and fine aggregates as approved by the Engineer. Blend the cement and aggregate before bagging the mix.

E.....Bags and Batch Identification

Provide moisture-proof bags resistant to tearing.

Print the following on the bags:

- (1) The phrase, "Mn/DOT GRADE 3U18 CONCRETE PATCH MIX",
- (2) Weight of the bag in pounds [kilograms],
- (3) Mix date, and
- (4) The instructions for mixing into concrete.

3105.3 SAMPLING AND TESTING

Sample individual materials and the aggregate blend in accordance with an approved Quality Control Program before blending at the bagging site.

3106 HYDRATED LIME

3106.1 SCOPE

Provide hydrated lime for use in soil drying or stabilization and for use in mortar for non-sewer applications or road pavement mixes.

3106.2 REQUIREMENTS

A.....Soil Drying/Stabilization

Provide hydrated lime for use in soil drying or stabilization meeting the requirements of AASHTO M 216.

B.....Mortar for Other Applications

For use in mortar, provide Type S hydrated lime meeting the requirements of ASTM C 207.

3106.3 SAMPLING AND TESTING

Provide sample at rates and sizes as required by the Schedule of Materials Control and the contract.

3107 MASONRY MORTAR

3107.1 SCOPE

Provide masonry mortar for use in sewer and other applications.

3107.2 REQUIREMENTS

A.....Sewer Application

Provide either bag mix or site mixed mortar meeting the following requirements:

A.1.....Bag Mix

Provide a dry, pre-blended, air-entrained, Type S or Type M bagged mortar mix meeting the requirements of ASTM C 270 and containing an air content of at least 8 percent.

A.2.....Site Mixed

Provide a mortar consisting of one part Type S or Type M masonry cement meeting the requirements of ASTM C 91 blended with from two and one-quarter parts to three parts of mortar sand in accordance with 3128, "Aggregate for Use in Masonry Mortar."

B Other Applications

For applications other than for sewers, provide masonry mortar in accordance with ASTM C 270 based on the type of mortar required by the contract.

3107.3 SAMPLING AND TESTING

For bag mixed masonry mortar, provide a statement of compliance meeting the requirements of ASTM C 270 for air-entrained mortar. Label the type of mortar mix, either Type S or Type M, on each bag.

For site mixed masonry mortar, provide a statement of compliance meeting the requirements of ASTM C 91. Label the type of mortar mix, either Type S or Type M, on each bag. Provide samples for site mixed masonry mortar meeting the requirements of the Schedule of Materials Control and as required by the contract.

For applications other than for sewer applications, provide samples meeting the requirements of the Schedule of Materials Control and as required by the contract.

3113 ADMIXTURES FOR CONCRETE

3113.1 SCOPE

Provide admixtures for use in concrete applications.

3113.2 GENERAL

Provide admixtures in accordance with the following:

A.....Class I — Accelerating, Retarding, and Water-Reducing Admixtures

- (1) Type A — Water-reducing
- (2) Type B — Retarding
- (3) Type C — Accelerating
- (4) Type D — Water-reducing and retarding
- (5) Type E — Water-reducing and accelerating
- (6) Type F — Water-reducing, high range
- (7) Type G — Water-reducing, high range and retarding
- (8) Type S — Specific performance admixtures

B.....Class II — Air-Entraining Admixtures

C.....Class III — Calcium Chloride

3113.3 REQUIREMENTS

A.....Materials

Provide Class I admixtures from the Approved/Qualified Products List meeting the requirements of ASTM C 494. Provide Class II admixtures meeting the requirements of AASHTO M 154, except the tests for bleeding, bond strength, and volume change are not required.

Provide Class III admixtures from the Approved/Qualified Products List meeting the requirements of AASHTO M 144.

B.....Acceptance

Submit certified test reports including a print of the materials safety data sheet (MSDS), infrared spectrum and one-quart sample for the proposed Class I or Class II admixture from a CCRL Laboratory for each admixture. The Department will use the certified test results to determine if the admixtures meet the requirements of this section.

3113.4 SAMPLING AND TESTING

Take samples as specified in the Schedule of Materials Control.

The Department may perform tests on samples taken from the product proposed or on samples submitted and certified by the manufacturer as representative of the admixture to be supplied.

3115 FLY ASH FOR USE IN PORTLAND CEMENT CONCRETE

3115.1 SCOPE

Provide fly ash for use in concrete applications.

3115.2 REQUIREMENTS

Provide fly ash from the certified source listed on the Approved/Qualified Products List, meeting the requirements of ASTM C 618, Class F or Class C, except as modified by the following table:

Table 3115-1 Mn/DOT Modified Fly Ash Requirements		
Requirement	Class F	Class C
Chemical requirements:		
Loss on ignition	≤ 3.0 %	≤ 3.0 %
Available alkalies as Na ₂ O	≤ 3.0 %	≤ 3.0 %
Physical requirements:		
Specific gravity, maximum variation from established value *	≤ ±0.12	≤ ±0.12
* The established value for specific gravity is that value which is stated in the source approval given by the Materials Manufacturer.		

The use of fly ash produced at plants where lime is directly injected into the boiler for sulfur removal, is prohibited in Portland cement concrete.

Ensure the following standardized Fly Ash Certification Statement is included with delivery invoices: “(insert company name) certifies that the fly ash produced at (insert power plant and location) conforms to ASTM C 618 and Mn/DOT Specification 3115 for Class (insert class) fly ash.”

Do not change the source or color, or both, of fly ash on a project without the written approval of the Engineer.

The Department will consider fly ash meeting the requirements of both Class C and Class F as Class C fly ash.

3115.3 SAMPLING AND TESTING

Provide samples for testing meeting the requirements of the Schedule for Materials Control.

AGGREGATE

3126 FINE AGGREGATE FOR PORTLAND CEMENT CONCRETE

3126.1 SCOPE

Provide fine aggregate for use in portland cement concrete.

3126.2 REQUIREMENTS

A..... General

Provide fine aggregate consisting of clean, sound, durable particles, uniform in quality and free from wood, bark, roots and other deleterious material.

The Engineer may consider the following as the basis for acceptance of fine aggregate for portland cement concrete:

- (1) Results of laboratory tests,
- (2) Behavior under natural exposure conditions,
- (3) Behavior of other portland cement concrete with aggregate from the same or similar geological formations or deposits, and
- (4) Any other tests or criteria as deemed appropriate by the Engineer in conjunction with the Concrete Engineer.

B..... Composition

Provide fine aggregate from natural sand. If producing fine and coarse aggregates simultaneously from natural gravel deposits during the same operation, the Contractor may provide fine aggregate containing particles of crushed rock.

C..... Washing

Wash the fine aggregate.

D..... Deleterious Material

Provide fine aggregate containing a cumulative quantity of deleterious materials in accordance with Table 3126-1.

Table 3126-1 Deleterious Materials	
Quality Test	Maximum Percent by Weight
Shale, Alkali, Mica, and Soft and Flaky Particles, Cumulative Total	2.5
Coal and Lignite, Cumulative Total	0.3

E..... Organic Impurities

Provide fine aggregate free of injurious quantities of organic impurities. The Engineer will reject aggregates that produce a color darker than the standard color when tested in accordance with AASHTO T 21, unless the mortar specimens pass the mortar strength requirements specified in 3126.2.F, "Structural Strength."

F..... Structural Strength

The Engineer will test the structural strength of fine aggregate in mortar specimens in accordance with AASHTO T 71 and Table 3126-2. The Engineer will prepare control mortar specimens using Ottawa sand with a Fineness Modulus (FM) from 2.30 to 2.50.

Table 3126-2 Structural Strength in Fine Aggregate	
Mortar Specimens Containing:	Compressive Strength
Type I/II Portland Cement	≥ 90% of control at 7 days
Type III Portland Cement	≥ 90% of control at 3 days

G..... Gradation Requirements

Produce fine aggregate in accordance with the gradation requirements in Table 3126-3.

Table 3126-3 Fine Aggregate Gradation Requirements	
Sieve Size	Percent Passing*
¾ in [9.50 mm]	100
No. 4 [4.75 mm]	95 – 100
No. 8 [2.36 mm]	80 – 100
No. 16 [1.18 mm]	55 – 85
No. 30 [600 µm]	30 – 60
No. 50 [300 µm]	5 – 30
No. 100 [150 µm]	0 – 10
No. 200 [75 µm]	0 – 2.5

* Percent passing by weight through square opening sieves.

H..... Requirements for Uniformity of Grading

The uniformity of grading is determined by the Fineness Modulus (FM) of the fine aggregate.

Both the Engineer and Contractor will determine the FM of fine aggregate by adding the cumulative percent passing the following sieves, dividing by 100, and subtracting from 7:

- (1) ¾ in [9.50 mm],
- (2) No. 4 (4.75 mm),
- (3) No. 8 [2.36 mm],
- (4) No. 16 [1.18 mm],
- (5) No. 30 [600 µm],
- (6) No. 50 [300 µm], and
- (7) No. 100 [150 µm].

Do not allow the material to deviate from the FM by greater than 0.20. Contact the Engineer, in conjunction with the Concrete Engineer, for an adjustment if the FM approaches the tolerance limit.

3126.3 SAMPLING AND TESTING

Provide fine aggregates in accordance with Table 3126-4.

Table 3126-4 Preliminary Fine Aggregate Testing	
Aggregate	Notification and Testing Required
New source	Notify the Engineer at least 1 month before use. Perform new source concrete aggregate testing.
Previously tested aggregate	Notify the Engineer at least 2 weeks before use. Perform additional testing as required by the Engineer in conjunction with the Concrete Engineer.

Sample and test fine aggregate in accordance with Table 3126-5.

Table 3126-5	
Fine Aggregate Test Methods	
Test	Testing Method
Sampling	Concrete Manual
Sieve analysis	Concrete Manual
Deleterious substances	Laboratory Manual Method 1207
Quantity of material passing the No. 200 [75 µm] sieve	Concrete Manual
Organic impurities (color plate)	AASHTO T 21
Structural strength	AASHTO T 71
Specific gravity and absorption	Laboratory Manual Method 1205
Alkali silica reactivity	Laboratory Manual Method 1222

3127 FINE AGGREGATE FOR BITUMINOUS SEAL COAT

3127.1 SCOPE

Provide fine aggregate for use in bituminous seal coat.

3127.2 REQUIREMENTS

A..... Composition

Provide aggregate for use in bituminous seal coat meeting the following requirements:

- (1) Consisting of sound, durable particles of sand, gravel or crushed stone,
- (2) Clean,
- (3) Uniform in quality,
- (4) Free of deleterious materials and
- (5) Meeting the requirements of Class A, B or C in accordance with 3137.2.B, "Classification."

B..... Gradation and Quality

Provide fine aggregate for bituminous seal coat meeting the following gradation requirements:

Table 3127-1						
Fine Aggregate for Bituminous Seal Coat, % Passing by Weight						
Sieve Size	FA-1	FA-2	FA-2½	FA-3	FA-3½	Job Mix Formula Tolerance %
½ in [12.5 mm]	100	100	100	100	100	—
¾ 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 [4.75mm]	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	—

Provide fine aggregate for bituminous seal coat meeting the following quality test requirements:

Table 3127-2 Fine Aggregate Durability for Bituminous Seal Coat Meeting the Requirements of AASHTO T96 as Modified by Mn/DOT					
Material Tests	FA-1	FA-2	FA-2½	FA-3	FA-3½
Shale, %	≤ 5	≤ 5	≤ 5	≤ 3	≤ 2
Flakiness index, % *	—	≤ 25	≤ 25	≤ 25	≤ 25
One Face Crush. %	≥ 80	≥ 80	≥ 80	≥ 80	≥ 80
Insoluble residue for the portion of quarried carbonate aggregates passing the No. 200 sieve, %	≤ 10	≤ 10	≤ 10	≤ 10	≤ 10
Los Angeles Rattler, % loss	—	—	—	≤ 35	≤ 35
* Test aggregate retained on each sieve, if weight of retained aggregate comprises at least 4 percent of the total sample weight.					
For Class C aggregates only.					

3127.3 SAMPLING AND TESTING — (BLANK)

Report the No. 200 sieve results to the nearest 0.1 percent and all other sieve results to the nearest 1 percent.

A..... Sampling & Sieve Analysis MnDOT Bituminous Manual

B..... Flakiness Laboratory Manual Method 1223

C..... Shale Tests Laboratory Manual Method 1209

D..... Los Angeles Rattler Loss Laboratory Manual Method..... 1210

E..... Crushing Test Laboratory Manual Method..... 1214

F..... Loose Weight of Aggregate MN Seal Coat Handbook MN/RC-2006-34

G..... Bulk Specific Gravity Laboratory Manual Method 1205

H..... Insoluble Residue Laboratory Manual Method 1221

3128 AGGREGATE FOR USE IN MASONRY MORTAR

3128.1 SCOPE

Provide fine aggregate for use in masonry mortar.

3128.2 REQUIREMENTS

Provide aggregate for use in masonry mortar meeting the requirements of ASTM C 144. The gradation requirements of ASTM C 144 are shown in Table 3128-1.

Table 3128-1 Mortar Aggregate Gradation Limits	
Sieve Size	Percent Passing
No. 4 [4.75 mm]	100
No. 8 [2.36 mm]	95 – 100
No. 16 [1.18 mm]	70 – 100
No. 30 [600 μm]	40 – 75
No. 50 [300 μm]	10 – 35
No. 100 [150 μm]	2 – 15
No. 200 [75 μm]	0

The Engineer may allow aggregate meeting the gradation requirements of 3126.2.G, “Gradation Requirements,” for joints thicker than ½ in [12.5 mm].

3128.3 SAMPLING AND TESTING — (BLANK)

3135 MODIFIED AGGREGATE BASES

3135.1 SCOPE

This specification lists the quality requirements for modified aggregate bases used for 2215, “Full Depth Reclamation” (FDR).

3135.2 REQUIREMENTS

A General

Produce aggregate materials that have uniform: appearance, texture, moisture content, and performance characteristics.

B Gradation

Provide modified aggregate bases for FDR mixtures in accordance with Table 3135-1.

Table 3135-1 Gradation Requirements	
Sieve Size, in [mm]	Percent Passing
3 [75]	100
2 [50]	97 – 100
Note 1: Exclude rock that is larger the 2 inches [50 mm], in the gradation calculations, when it originates from material below the reclaimed bituminous pavement.	

C Add Materials

Supply materials as required by the contract.

3135.3 SAMPLING AND TESTING

Test the FDR mixture at the rates specified in the Schedule of Materials Control.

A.....Sampling and Sieve Analysis Grading and Base Manual

3136 DRAINABLE BASES**3136.1 SCOPE**

This specification lists the quality requirements for drainable bases types: Open Graded Aggregate Base (OGAB) and Drainable Stable Base (DSB) used for 2212, "Drainable Aggregate Base".

3136.2 REQUIREMENTS**A Aggregate Composition**

Provide certified aggregate along with Form G&B – 104.

A.1 Virgin Aggregates

Provide virgin aggregates meeting the following requirements:

- (1) Comprised of naturally occurring mineral materials and
- (2) Does not contain topsoil, organics or disintegrating rock as defined in Laboratory Manual section 1209.

B Quality and Gradation Requirements

Meet the requirements of Table 3136-1.

Table 3136-1 Drainable Base Requirements		
Total Percent Passing Requirement	Type	
	OGAB	DSB
1½ in [37.5 mm] Sieve	100	100
1 in [25.0 mm] Sieve	95 – 100	-
¾ in [19.0 mm] Sieve	65 – 95	75 – 100
⅜ in [9.5 mm] Sieve	30 – 65	45 – 75
No. 4 [4.75 mm] Sieve	10 – 35	30 – 60
No. 10 [2.00 mm] Sieve	3 – 20	10 – 35
No. 40 [425 µm] Sieve	0 – 8	5 – 20
No. 200 [75 µm] Sieve	0 – 3.5	0 – 5.0, for class B or C. 0 – 6.5, for class A. Classes per specification 3137.
Other Requirements	OGAB	DSB
D_{60}/D_{10} *	≥ 4.0	≥ 8.0
Minimum Crushing (Two face)	85%	60%
Maximum Los Angeles Rattler Loss (LAR)	40%	40%
Table 3136-1 Drainable Base Requirements		
Other Requirements	OGAB	DSB
Maximum Acid Insoluble Residue (IR) Minus No. 200 [75 µm] sieve †	10%	10%
Maximum Spall – Total Sample	5.0%	5.0%
* D_{60} is the diameter of the soil particle of which 60 percent is smaller, by weight. D_{10} is the diameter of the soil particle of which 10 percent is smaller, by weight.		
Material crushed from quarries is considered crushed material.		
† For drainable base composed of crushed carbonate quarry rock.		

3136.3 SAMPLING AND TESTING

Test in accordance with the following procedures:

A.....Sieve Analysis Laboratory Manual Method1202 & 1203
B.....Coarse Aggregate Angularity Laboratory Manual Method1214
C.....Los Angeles Rattler Loss Laboratory Manual Method1210
D.....Insoluble Residue Laboratory Manual Method1221
E.....Spall Laboratory Manual Method1209

3137 COARSE AGGREGATE FOR PORTLAND CEMENT CONCRETE

3137.1 SCOPE

Provide coarse aggregate for use in portland cement concrete.

3137.2 REQUIREMENTS

A.....General

Provide coarse aggregate consisting of clean, sound, durable particles, uniform in quality, and free from wood, bark, roots, and other deleterious material.

The Engineer, in conjunction with the Concrete Engineer, may consider the following as the basis for acceptance of coarse aggregate for portland cement concrete:

- (1) Results of laboratory tests,
- (2) Behavior under natural exposure conditions,
- (3) Behavior of other portland cement concrete with aggregate from the same or similar geological formations or deposits, and
- (4) Any other tests or criteria as deemed appropriate by the Engineer, in conjunction with the Concrete Engineer.

B.....Classification

Provide coarse aggregate meeting the requirements of one of the following classifications:

- (1) Class A: Crushed quarry rock including quartzite, gneiss, and granite, or mine trap rock including basalt, diabase, gabbro, and other igneous rock types. Class A aggregate may contain no greater than 4.0 percent non-Class A aggregate. The Department will not allow the intentional blending or adding of non-Class A aggregate.
- (2) Class B: All other crushed quarry or mine rock types including carbonates, rhyolite, and schist.
- (3) Class C: Natural or partly crushed gravel obtained from a natural gravel deposit.
- (4) Class D: Mixture of at least two other classes of coarse aggregate. The Engineer, in conjunction with the Concrete Engineer, will determine the suitability of the Class D aggregate for the proposed use including proportioning.
- (5) Class R: Aggregate obtained from recycling concrete. The Engineer, in conjunction with the Concrete Engineer, will determine the suitability of the Class R aggregate for the proposed use, including proportioning.

C.....Washing

Wash Class B, Class C, Class D, and Class R coarse aggregate. Wash Class A aggregate as needed to comply with the requirements of Table 3137-1.

D.....Quality

Quality requirements are based on each individual fraction unless otherwise approved by the Engineer, in conjunction with the Concrete Engineer, except for the following:

- (1) If 100 percent of the fractions from a single source pass the 1 in [25 mm] sieve, base quality requirements on the composite value of the combined aggregates.
- (2) If less than 100 percent of the fractions from a single source pass the 1 in [25 mm] sieve, base the quality requirements in accordance with the following:
 - (2.1) For fractions passing the 1 in [25 mm] sieve, base the quality requirement on the composite value of the combined aggregates;
 - (2.2) For fractions greater than or equal to 1 in [25 mm], base the quality requirement on each individual aggregate fraction.

D.1 Coarse Aggregate for General Use

Provide coarse aggregate for general use concrete in accordance with Table 3137-1. Table 3137-1		
Coarse Aggregate for General Use		
Quality Test		Maximum Percent by Weight
(a)	Shale:	
	Fraction retained on the ½ in [12.5 mm] sieve	0.4
	Fraction retained on the No. 4 [4.75 mm] sieve, as a percentage of the total material	0.7
(b)	Soft iron oxide particles (paint rock and ochre)	0.3
(c)	Total spall materials*:	
	Fraction retained on the ½ in [12.5 mm] sieve	1.0
	Fraction retained on the No. 4 [4.75 mm] sieve, as a percentage of the total material	1.5
(d)	Soft particles	2.5
(e)	Clay balls and lumps	0.3
(f)	Sum of (c) total spall materials, (d) soft particles, and (e) clay balls and lumps†	3.5
(g)	Slate	3.0
(h)	Flat or elongated pieces‡	15.0
(i)	Quantity of material passing No. 200 [75 µm] sieve:	
	Class A and Class B aggregates#	1.5
	Class C and Class D aggregates§	1.0
(j)	Los Angeles Rattler, loss on total sample	40.0
(k)	Soundness of magnesium sulfate**	15.0
* Includes the percentages retained by shale and soft iron oxide particles, plus other iron oxide particles, unsound cherts, pyrite, and other materials with similar characteristics. Exclusive of shale, soft iron oxide particles, and total spall materials. † Sum of the total spall materials, soft particles, and clay balls and lumps. For total spall materials, use the percent in the total sample retained on the No. 4 [4.75 mm] sieve. ‡ Thickness less than 25 percent of the maximum width. Length greater than 3 times the maximum width. # Each individual fraction at the point of placement consists of dust from the fracture and free of clay or shale. § For each individual fraction at the point of placement. ** Loss at 5 cycles for any fraction of the coarse aggregate. Do not blend materials from multiple sources to obtain a fraction meeting the sulfate soundness requirement.		

D.2..... Coarse Aggregate for Bridge Superstructure

Provide coarse aggregate in accordance with 3137.2.D.1, "Coarse Aggregate for General Use," except as modified by Table 3137-2, for use in the following:

- (1) Bridge superstructure (deck, railing, posts, curbs, sidewalks, and median strips);
- (2) Approach panels; and
- (3) Precast concrete panel facings for Mechanically Stabilized Earth walls.

Table 3137-2		
Coarse Aggregate for Bridge Superstructure		
Quality Test		Maximum Percent by Weight
(a)	Shale:	
	Fraction retained on the ½ in [12.5 mm] sieve	0.2
	Fraction retained on the No. 4 [4.75 mm] sieve as a percentage of the total material	0.3
(b)	Soft iron oxide particles (paint rock and ochre)	0.2
(c)	Total spall materials*:	
	Fraction retained on the No. 4 [4.75 mm] sieve as a percentage of the total material	0.5
(d)	Soft particles	2.5
(e)	Clay balls and lumps	0.3
(f)	Sum of (c) total spall materials, (d) soft particles, and (e) clay balls and lumps, use the percent in the total sample retained on the No. 4 [4.75 mm] sieve	3.0
(g)	Absorption for Class B aggregate	1.75
(h)	Absorption for Class B aggregate for all concrete bridge decks	1.10
(i)	Carbonate in Class C and Class D aggregates by weight	30.0
<p>* Includes the percentages retained by shale and soft iron oxide particles, plus other iron oxide particles, unsound cherts, pyrite, and other materials with similar characteristics.</p> <p> Exclusive of shale, soft iron oxide particles, and total spall materials.</p> <p>† Sum of the total spall materials, soft particles, and clay balls and lumps. For total spall materials, use the percent in the total sample retained on the No. 4 [4.75 mm] sieve.</p>		

D.3..... Coarse Aggregate for Concrete Pavement

Provide coarse aggregate in accordance with 3137.2.D.1, "Coarse Aggregate for General Use," except as modified by Table 3137-3, for use in the following:

- (1) Concrete pavement, and
- (2) Concrete pavement rehabilitation.

Table 3137-3	
Coarse Aggregate for Concrete Pavement	
Quality Test	Maximum Percent by Weight
(a) Absorption for Class B aggregate	1.75
(b) Carbonate in Class C aggregate by weight	30.0

E Gradation

Provide coarse aggregate in accordance with Table 3137-4 including all sizes within the specified limits. The Department defines coarse aggregate as the uniform product of the producing plant, unless some sizes are removed to meet the gradation requirements. Do not use broken or non-continuous gradations.

If the coarse aggregate contains less than 100 percent passing the 1 in [25 mm] sieve, use at least two fractions to proportion the coarse aggregate. Base gradation requirements on the composite value of the combined coarse aggregates.

If producing Class R aggregate, remove reinforcing steel from the concrete and any concrete material passing the No 4 [4.75 mm] sieve.

Table 3137-4									
Coarse Aggregate Designation for Concrete,									
<i>percent by weight passing square opening sieves</i>									
Aggregate	2 in [50 mm]	1½ in [37.5 mm]	1¼ in [31.5 mm]	1 in [25.0 mm]	¾ in [19.0 mm]	½ in [16.0 mm]	½ in [12.5 mm]	¾ in [9.5 mm]	No.4 [4.75 mm]
CA-00	—	—	—	100	95 – 100	—	—	—	0 – 10
CA-15	100	95 – 100	—	—	35 – 65	—	—	5 – 25	0 – 7
CA-25	100	95 – 100	—	—	50 – 80	—	—	20 – 40	0 – 7
CA-35	—	100	95 – 100	—	55 – 85	—	—	20 – 45	0 – 7
CA-45	—	—	100	95 – 100	65 – 95	—	—	25 – 55	0 – 7
CA-50	—	—	—	100	85 – 100	—	—	30 – 60	0 – 12
CA-60	—	—	—	—	100	85 – 100	—	40 – 70	0 – 12
CA-70	—	—	—	—	—	100	85 – 100	50 – 100	0 – 25
CA-80*	—	—	—	—	—	—	—	100	55 – 95

* Do not allow greater than 5 percent to pass the No. 50 [300 µm] sieve.

3137.3 SAMPLING AND TESTING

Sample and test coarse aggregate fractions separately in accordance with Table 3137-5.

Table 3137-5	
Preliminary Coarse Aggregate Testing	
Aggregate	Notification and Testing Requirement
New source	Notify the Engineer at least 1 month before use. Perform new source concrete aggregate testing.
Previously tested aggregate	Notify the Engineer at least 2 weeks before use. Perform additional testing as directed by the Engineer, in conjunction with the Concrete Engineer.

Sample and test coarse aggregate in accordance with Table 3137-6.

Test	Testing Method
Sampling	Concrete Manual
Sieve analysis	Concrete Manual
Shale test	Laboratory Manual Method 1207
Quantity of material passing the No. 200 [75 µm] sieve	Concrete Manual
Specific gravity and absorption	Laboratory Manual Method 1204
Density	AASHTO T 19 or Laboratory Manual Method 1211
Los Angeles Rattler loss	AASHTO T 96
Void content	AASHTO T 19* or Laboratory Manual Method 1211
Deleterious materials	Laboratory Manual Method 1209
Soundness; magnesium sulfate	Laboratory Manual Method 1219
Soft particles	Laboratory Manual Method 1218
Flat or elongated pieces	ASTM D 4791
Clay balls or lumps	Concrete Manual
* Base the void content on an oven-dry and compacted-by-rodding condition of the aggregate and a value of 62.4 lb per cu. ft [1,000 kg per cu. m] for water.	

3138 AGGREGATE FOR SURFACE AND BASE COURSES

3138.1 SCOPE

Provide certified aggregate along with Form G&B-104 for 2118, 2211 and 2221.

Note that 5Q is a new gradation, which a designer may designate for use as a base, and would most commonly be produced at a quarry.

3138.2 REQUIREMENTS

A General

Use aggregate sources meeting the requirements of 1601, "Source of Supply and Quality."

Provide certified aggregate materials that have uniform: appearance, texture, moisture content and performance characteristics.

Provide binder soils from sources meeting the requirements of 3146, "Binder Soil." Add binder soils during the crushing and screening operations.

B Virgin Materials

Provide virgin aggregates meeting the following requirements:

- (1) Comprised of naturally occurring mineral materials, and contains no topsoil, organics or disintegrating rock as defined in Laboratory Manual section 1209,
- (2) Class 2 must be composed of 100% crushed quarry rock and
- (3) Conforms to the quality requirements of Table 3138-1.

Requirement	Class			
	1 and 2	3 and 4	5 and 5Q	6
Max Shale, if No. 200 ≤ 7 % by mass	NA	10.0%	10.0%	7.0%
Max Shale, if No. 200 > 7 % by mass	NA	7.0%	7.0%	7.0%
Minimum Crushing Requirements *	NA	NA	10%	15%
Maximum Los Angeles Rattler (LAR) loss from carbonate quarry rock	40%	40%	40%	35%
Maximum Insoluble residue for the portion of quarried carbonate aggregates passing the No. 200 sieve	10%	10%	10%	10%

* Material crushed from quarries is considered crushed material.

C Recycled Materials

The Contactor may substitute recycled aggregates for virgin aggregates, if meeting the following requirements:

- (1) Recycled aggregates contain only recycled asphalt pavement (RAP), recycled concrete materials, recycled aggregate materials, or certified recycled glass, and
- (2) Must meet the requirements of Table 3138-2.

Requirement	Classes 1, 3, 4, 5, 5Q and 6
Maximum Bitumen Content of Composite	3.5%
Maximum Masonry block %	10%
Maximum percentage of glass *	10%
Maximum size of glass *	¾ in [19 mm]
Crushing (Class 5, 5Q and 6)	10% for Class 5 and 5Q † 15% for Class 6 †

* Glass must meet certification requirements on the Grading and Base website. Combine glass with other aggregates during the crushing operation.
† If material ≥ 20% (RAP + Concrete), Class 5 and 5Q crushing requirements are met.
† If material ≥ 30% (RAP + Concrete), Class 6 crushing requirement is met.
|| Material crushed from quarries is considered crushed material.

D Surfacing Aggregates

Provide surfacing aggregates in accordance with 3138.2.A, "General," 3138.2.B, "Virgin Materials," and 3138.2.C, "Recycled Materials," and meeting the following requirements:

- (1) 100 percent of the material passes the ¾ in [19.0 mm] sieve,
- (2) Does not use glass,
- (3) Recycled concrete materials may only be used for the roadway shoulders and
- (4) There is no restriction on the bitumen content, if used for shouldering.

Note: Class 2 must be composed of 100% crushed quarry rock per 3138.2B3.

E Gradation Requirements

- (1) For products containing less than 25 percent recycled materials, conform to Table 3138-3.
- (2) For products containing 25 percent or more recycled materials and less than 75% recycled concrete, conform to Table 3138-4.
- (3) For products containing 75 percent or more recycled concrete, conform to Table 3138-5.

- (4) Perform gradation tests prior to bituminous extraction.

Table 3138-3 Base and Surfacing Aggregate (containing less than 25 percent recycled aggregates) Total Percent Passing							
Sieve Size	Class 1	Class 2	Class 3	Class 4	Class 5	Class 5Q	Class 6
2 in	—	—	100	100	—	100	—
1½ in	—	—	—	—	—	—	—
1 in	—	—	—	—	100	65 – 95	100
¾ in	100	100	—	—	90 – 100	45 – 85	90 – 100
⅜ in	65 – 95	65 – 90	—	—	50 – 90	35 – 70	50 – 85
No. 4	40 – 85	35 – 70	35 – 100	35 – 100	35 – 80	15 – 45	35 – 70
No. 10	25 – 70	25 – 45	20 – 100	20 – 100	20 – 65	10 – 30	20 – 55
No. 40	10 – 45	12 – 30	5 – 50	5 – 35	10 – 35	5 – 25	10 – 30
No. 200	8.0–15.0	5.0–13.0	5.0–10.0	4.0–10.0	3.0–10.0	3.0–10.0	3.0–7.0

Table 3138-4 Base and Surfacing Aggregate (containing 25% or more recycled aggregates & less than 75% recycled concrete) Total Percent Passing*						
Sieve Size	Class 1	Class 3	Class 4	Class 5	Class 5Q	Class 6
2 in	—	100	100	—	100	—
1½ in	—	—	—	100	—	100
1 in	—	—	—	—	65 – 95	—
¾ in	100	—	—	90 – 100	45 – 85	90 – 100
⅜ in	65 – 95	—	—	50 – 90	35 – 70	50 – 85
No. 4	40 – 85	35 – 100	35 – 100	35 – 80	15 – 45	35 – 70
No. 10	25 – 70	20 – 100	20 – 100	20 – 65	10 – 30	20 – 55
No. 40	10 – 45 † 5 – 45	5 – 50	5 – 35	10 – 35	5 – 25	10 – 30
No. 200	5.0 – 15.0 † 0 – 15.0	0 – 10.0	0 – 10.0	0 – 10.0	0 – 10.0	0 – 7.0

*Add letters in parentheses for each aggregate blend designating the type of recycled products included in the mixture.
(B) = Bituminous, (C) = Concrete, (G) = Glass
(BC) = Bituminous and Concrete, (BG) = Bituminous and Glass
(CG) = Concrete and Glass, (BCG) = Bituminous, Concrete and Glass

† Note: For Class 1, if the bitumen content is $\geq 1.5\%$, the gradation requirement is modified to 5 – 45% for the #40 Sieve and 0 – 15.0% for the #200 Sieve.

Table 3138-5						
Base and Surfacing Aggregate						
(containing more than 75 percent recycled concrete)						
Total Percent Passing*						
Sieve Size	Class 1	Class 3	Class 4	Class 5	Class 5Q	Class 6
2 in	—	100	100	—	100	—
1½ in	—	—	—	100		100
1 in	—	—	—		65 – 95	
¾ in	100	—	—	90 – 100	45 – 85	90 – 100
⅜ in	65 – 95	—	—	50 – 90	35 – 70	50 – 85
No. 4	40 – 85	35 – 100	35 – 100	35 – 80	15 – 45	35 – 70
No. 10	25 – 70	20 – 100	20 – 100	20 – 65	10 – 30	20 – 55
No. 40	10 – 45	0 – 8	0 – 8	0 – 8	0 – 8	0 – 8
No. 200	5.0 – 15.0	0 – 3.0	0 – 3.0	0 – 3.0	0 – 3.0	0 – 3.0

* Add letters in parentheses for each aggregate blend designating the type of recycled products included in the mixture.
 (B) = Bituminous, (C) = Concrete, (G) = Glass, (BC) = Bituminous and Concrete,
 (BG) = Bituminous and Glass, (CG) = Concrete and Glass,
 (BCG) = Bituminous, Concrete and Glass

3138.3 SAMPLING AND TESTING

Report the No. 200 sieve results to the nearest 0.1 percent and all other sieve results to the nearest 1 percent.

- A.....Sampling, Sieve Analysis and Crushing Tests Grading and Base Manual**
- B.....Los Angeles Rattler Loss Laboratory Manual Method..... 1210**
- C.....Shale Tests Laboratory Manual Method 1207 & 1209**
- D.....Bitumen Content Laboratory Manual Method..... 1852**
- E.....Insoluble Residue Laboratory Manual Method 1221**
- F.....Reclaimed Glass AGI Visual Method (AGI Data sheet 15.1 and 15.2)**

3139 GRADED AGGREGATE FOR BITUMINOUS MIXTURES

3139.1 SCOPE

Provide graded aggregate for use in bituminous mixtures.

3139.2 PLANT MIXED ASPHALT REQUIREMENTS

A Composition

Provide graded aggregate composed of any combination of the following sound durable particles as described in 3139.2B.

Do not use graded aggregate containing objectionable materials including:

- (1) Metal,
- (2) Glass,
- (3) Wood,
- (4) Plastic,
- (5) Brick, or
- (6) Rubber.

Provide coarse aggregate free of coatings of clay and silt.

Do not add soil materials such as clay, loam, or silt to compensate for a lack of fines in the aggregate.

Do not blend overburden soil into the aggregate.

Feed each material or size of material from an individual storage unit at a uniform rate.

Do not place blended materials from different sources, or for different classes, types, or sizes together in one stockpile unless approved by the Engineer as a Class E aggregate.

B Classification

B.1 Class A

Provide crushed igneous bedrock consisting of basalt, gabbro, granite, gneiss, rhyolite, diorite, and andesite. Rock from the Sioux Quartzite Formation may contain no greater than 4.0 percent non-Class A aggregate. Do not blend or add non-Class A aggregate to Class A aggregate.

B.2 Class B

Provide crushed rock from other bedrock sources such as carbonate and metamorphic rocks (Schist).

B.3 Class C

Provide natural or partly crushed natural gravel obtained from a natural gravel deposit.

B.4 Class D

Provide 100 percent crushed natural gravel produced from material retained on a square mesh sieve with an opening at least twice as large as Table 3139-2 allows for the maximum size of the aggregate in the composite asphalt mixture. Ensure the amount of carryover, material finer than the selected sieve, no greater than 10 percent of the Class D aggregate by weight.

B.5 Class E

Provide a mixture consisting of at least two of the following classes of approved aggregate:

- (1) Class A,
- (2) Class B, and
- (3) Class D.

B.6 Steel Slag

Steel slag cannot exceed 25% of the total mixture aggregate and be free from metallic and other mill waste.

The Engineer will accept stockpiles if the total expansion is no greater than 0.5 percent as determined by ASTM D 4792

B.7 Taconite Tailings

Obtain taconite tailings from ore mined westerly of a north-south line located east of Biwabik, Minnesota (R15W-R16W) or from ore mined in southwestern Wisconsin.

B.8 Recycled Asphalt Shingles (RAS)

Provide recycled asphalt shingles manufactured from waste scrap asphalt shingles (MWSS) or from tear-off scrap asphalt shingles (TOSS). Consider the percentage of RAS used as part of the maximum allowable Recycled Asphalt Pavement (RAP) percentage. See Table 3139-3.

B.8.A RAS Gradation.....MnDOT Laboratory Procedure 1801

Provide RAS in accordance with the following gradation requirements:

Table 3139-1 RAS Gradation	
Sieve size	Percent passing
½ in [12.5 mm]	100
No. 4 [4.75 mm]	90

B.8.B Binder Content

Determine the binder content using chemical extraction meeting the requirements of MnDOT Lab Procedure 1851 or 1852.

B.8.C Bulk Specific Gravity

The Contractor may use an aggregate bulk specific gravity (Gsb) of 2.650 in lieu of determining the shingle aggregate Gsb in accordance with MnDOT Lab Procedure 1205.

B.8.D Waste Materials

Do not allow extraneous materials including metals, glass, rubber, nails, soil, brick, tars, paper, wood, and plastics greater than 0.5 percent by weight of the graded aggregate as determined by material retained on the No. 4 [4.75 mm] sieve as specified in MnDOT Laboratory Procedure 1801.

B.8.E Stockpile

Do not blend an RAS stockpile with other salvage material. Do not blend MWSS and TOSS. The Contractor may blend virgin sand material with RAS to minimize agglomeration if the Contractor accounts for the blended sand in the final mixture gradation.

B.8.F Certification

Ensure the processor provides RAS certification on the following Department form “Scrap Asphalt Shingles from Manufacture Waste” or “Tear-Off Scrap Asphalt Shingles” at www.dot.state.mn.us/materials/bituminous.html

B.9 Crushed Concrete and Salvaged Aggregate

The Contractor may incorporate no greater than 50 percent of crushed concrete and salvaged aggregate in non-wear mixtures. Do not use crushed concrete in wearing courses.

B.10 Ash

Sewage sludge ash and waste incinerator ash are allowed as an aggregate source at a maximum of 5% of the total weight of the mixture. Sewage sludge ash for use as an aggregate source in wear or non-wear courses must be approved by examination with the Hazard Evaluation Process by MnDOT’s Office of Environmental Stewardship.

B.11 Recycled Asphalt Pavement (RAP)

B.11.A Aggregate Angularity

Provide combined RAP and virgin aggregates that meet the composite coarse and fine aggregate angularity for the mixture being produced.

B.11.B Objectionable Material

Do not use RAP containing objectionable materials including metal, glass, wood, plastic, brick, or rubber.

B.11.C Asphalt Binder Content

Determine the asphalt binder content using the MnDOT Lab Manual Method 1851 and 1852.

B.11.D Bulk Specific Gravity

Determine the bulk specific gravity in accordance with MnDOT Laboratory Procedure 1205 or 1815.

C Quality

C.1 Los Angeles Rattler Test MnDOT Laboratory Procedure 1210

Ensure a coarse aggregate loss no greater than 40 percent.

C.2 Soundness (Magnesium Sulfate) MnDOT Laboratory Procedure 1219

Maximum loss after 5 cycles on the coarse aggregate fraction (material retained on No. 4 [4.75 mm] sieve for any individual source within the mix) as follows:

- (1) Percent passing the $\frac{3}{4}$ in [19 mm] sieve to percent retained on the $\frac{1}{2}$ in [12.5 mm] sieve, $\leq 14\%$,
- (2) Percent passing the $\frac{1}{2}$ in [12.5 mm] sieve to percent retained on the $\frac{3}{8}$ in [9.5 mm] sieve, $\leq 18\%$,
- (3) Percent passing the $\frac{3}{8}$ in [9.5 mm] sieve to percent retained on the No. 4 [4.75 mm] sieve, $\leq 23\%$,
- (4) For the composite if all three size fractions are tested, the composite loss $\leq 18\%$, and acceptance will be granted if:
 - (4.1) If the Contractor meets the composite requirement, but fails to meet at least one of the individual components, the Engineer may accept the source if each individual component is no greater than 110 percent of the requirement for that component.
 - (4.2) If the Contractor meets each individual component requirement, but fails to meet the composite, the Engineer may accept the source if the composite is no greater than 110 percent of the requirement for the composite.

Coarse aggregate that exceeds the requirements in this section for material passing the No. 4 [4.75 mm] sieve cannot be used.

C.3 Spall Materials and Lumps MnDOT Laboratory Procedure 1219

Stop asphalt production if the percent of spall or lumps measured in the stockpile or cold feed exceeds the values listed in Table 3139-3. Determine lump compliance by dry batching.

C.4 Insoluble Residue Test MnDOT Laboratory Procedure 1221

Use Statewide (except for District 6)

If using Class B carbonate materials ensure the portion of the insoluble residue passing the No. 200 [75 μ m] sieve is no greater than 10 percent.

Use for District 6 ONLY.

If crushed carbonate quarry rock (limestone or dolostone) is used, the minus #200 [75 μ m] sized portion of the rock insoluble residue shall not exceed 10% by weight.

Blending of sources and/or beds with an insoluble residue up to 15% is allowed to meet the 10% insoluble residue requirement. Individual beds thinner than 6 inches [150 mm] or up to 5% of the total face height, are exempt from the 15% maximum insoluble residue requirement. However, the aggregate producer shall practice good quality control at all times and exclude poor quality stone to the extent practical, regardless of the bed thickness and/or pocket size and location.

No carbonate quarry rock from the Platteville Geological Formation is allowed.

D Gradation

Ensure the aggregate gradation broad bands meet the following requirements in accordance with AASHTO T-11 (passing the No. 200 [75 μ m] wash) and AASHTO T-27.

Sieve size	A	B	C	D
1 in [25.0 mm]	—	—	100	—
¾ in [19.0 mm]	—	100*	85 – 100	—
½ in [12.5 mm]	100*	85 – 100	45 – 90	—
⅜ in [9.5 mm]	85 – 100	35 – 90	—	100
No. 4 [4.75 mm]	60 – 90	30 – 80	30 – 75	65 – 95
No. 8 [2.36 mm]	45 – 70	25 – 65	25 – 60	45 – 80
No. 200 [0.075 mm]	2.0 – 7.0	2.0 – 7.0	2.0 – 7.0	3.0 – 8.0

* The Contractor may reduce the gradation broadband for the maximum aggregate size to 97 percent passing for mixtures containing RAP, if the oversize material originates from the RAP source. Ensure the virgin material meets the requirement of 100 percent passing the maximum aggregate sieve size.

Aggregate Blend Property	Traffic Level 2	Traffic Level 3	Traffic Level 4	Traffic Level 5
20 year Design ESAL's	<1 million	1 - 3 million	3 - 10 million	10 – 30 million
Min. Coarse Aggregate Angularity (ASTM D5821) (one face / two face), %- Wear (one face / two face), %- Non-Wear	30/- 30/-	55 / - 55 / -	85 / 80 60/ -	95 / 90 80 / 75
Min. Fine Aggregate Angularity (FAA) (AASHTO T304, Method A) %- Wear %-Non-Wear	40 40	42 40	44 40	45 40
Flat and Elongated Particles, max % by weight, (ASTM D 4791)	-	10 (5:1 ratio)	10 (5:1 ratio)	10 (5:1 ratio)
Min. Sand Equivalent (AASHTO T 176)	-	-	45	45
Max. Total Spall in fraction retained on the #4 [4.75mm] sieve – Wear Non-Wear	5.0 5.0	2.5 5.0	1.0 2.5	1.0 2.5
Maximum Spall Content in Total Sample – Wear Non-Wear	5.0 5.0	5.0 5.0	1.0 2.5	1.0 2.5
Maximum Percent Lumps in fraction retained on the #4 [4.75mm] sieve	0.5	0.5	0.5	0.5
Class B Carbonate Restrictions				
Maximum% -#4 [-4.75mm] Final Lift/All other Lifts	100/100	100/100	80/80	50/80
Maximum% +#4 [+4.75mm] Final Lift/All other Lifts	100/100	100/100	50/100	0/100
Max. allowable scrap shingles–MWSS ⁽¹⁾ Wear/Non Wear	5/5	5/5	5/5	5/5
Max. allowable scrap shingles –TOSS ⁽¹⁾ Final Lift/All other Lifts	5/5	5/5	0/5	0/0

(1) MWSS is manufactured waste scrap shingle and TOSS is tear-off scrap shingle.

3139.3 PERMEABLE ASPHALT STABILIZED STRESS RELIEF COURSE (PASSRC) AND PERMEABLE ASPHALT STABILIZED BASE (PASB) REQUIREMENTS

A Restrictions

Do not use recycled materials including glass, concrete, bituminous, shingles, ash, and steel slag.

B Gradation

The Gradation limits are also considered the Job Mix Formula (JMF) limits.

B.1 PASB

Table 3139-4 PASB Aggregate Gradation	
Sieve Size	Percent Passing
1 ½ inch [37.5 mm]	100
1 inch [25.0 mm]	95 - 100
¾ inch [19.0 mm]	85 - 95
3/8 inch [9.5 mm]	30 - 60
No. 4 [4.75 mm]	10 - 30
No. 8 [2.36 mm]	0 - 10
No. 30 [600 µm]	0 - 5
No. 200 [75 µm]	0 - 3

B.2 PASSRC

Table 3139-5 PASSRC Aggregate Gradation	
Sieve Size	Percent Passing
5/8 inch [16.0 mm]	100
1/2 inch [12.5 mm]	85 - 100
3/8 inch [9.5 mm]	50 - 100
No. 4 [4.75 mm]	0 - 25
No. 8 [2.36 mm]	0 - 5

C Quality

Will meet all requirements of 3139.2.C.1 through 3139.2.C.3.

3139.2.C.4 changes to: If using Class B carbonate materials ensure the portion of the insoluble residue passing the No. 200 [75 µm] sieve is no greater than 10 percent.

D Mixture Quality Requirements

Table 3139-6 Mixture Aggregate Requirements for PASSRC & PASB	
Aggregate Blend Property	
Coarse Aggregate Angularity (ASTM D5821) (one face/two face) % PASSRC ⁽¹⁾ PASB ⁽¹⁾	95/ -65
Fine Aggregate Angularity (FAA) (AASHTO T304, Method A) %	NA
Flat and Elongated Particles, max(2) % by weight, (ASTM D 4791)	NA
Clay Content (2) (AASHTO T 176)	NA
Total Spall in fraction retained on the 4.75mm [#4] sieve	3.0
Maximum Spall Content in Total Sample	5.0
Maximum Percent Lumps in fraction retained on the 4.75mm [#4] sieve	0.5

Note (1) Carbonate Restrictions: If Class B (as defined in 3139.2.B.2), crushed carbonate quarry rock (limestone or dolostone), is used in the mixture, or if carbonate particles in the material retained on the 4.75 mm [No. 4] sieve exceeds 55 percent, by weight, the minus 0.075 mm [# 200] sieve size portion of the insoluble residue shall not exceed 10 percent.

3139.4 ULTRA THIN BONDED WEARING COURSE (UTBWC) REQUIREMENTS.**A Restrictions**

Do not use recycled materials including glass, concrete, bituminous, shingles, ash, and steel slag.

B Quality

Will meet all requirements of 3139.2.C.

C Coarse Aggregate

Provide a Class A aggregate, as defined in 3139.2.B.1, in accordance with the following requirements:

Table 3139-7 UTBWC Coarse Aggregate Requirements		
Tests	MnDOT Laboratory Manual Method	Limit, %
Flat and elongated ratio at 3:1	1208	≤ 25
Los Angeles Rattler Test (LAR)	1210	≤ 40
Bulk Specific Gravity	1204	

D Fine Aggregate

Provide fine aggregate, passing the No. 4 [4.75 mm] sieve in accordance with the following requirements:

Table 3139-8 UTBWC Fine Aggregate Requirements		
Tests	Method	Limit, %
Sand equivalent*	AASHTO T 176	≥ 45
Uncompacted void content	MnDOT Laboratory Manual 1206	≥ 40
Bulk Specific Gravity	MnDOT Laboratory Manual 1205	

E Aggregate Gradation Broadband

Table 3139-9 UTBWC Aggregate Gradation Broadband	
Aggregate Size Typical application rates	3/8 inch [9.5 mm] 65-75 lbs/sy
Sieve Size	Gradation Broadband Limits % Passing
3/4 inch [19.0 mm]	
1/2 inch [12.5 mm]	100
3/8 inch [9.5 mm]	85 – 100
No. 4 [4.75 mm]	28 – 42
No 8 [2.36 mm]	21 – 33
No. 16 [1.18 mm]	14 – 24
No. 30 [600 µm]	9 – 20
No. 50 [300 µm]	6 – 15
No. 100 [150 µm]	5 – 11
No. 200 [75 µm]	3.0- 7.0

3139.5 MICRO-SURFACING REQUIREMENTS**A Restrictions**

Do not use recycled materials including glass, concrete, bituminous, shingles, ash, and steel slag.

B Gradation

Provide a Class A aggregate or Taconite Tailings as defined in 3139.2.B.1, “Graded Aggregate for Bituminous Mixtures”, in accordance with the gradation requirements of Table 3139-10, “Micro-Surfacing Gradation Limits and QC Tolerances”.

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 3/8 in [9.5 mm] sieve and retained on No. 16 [1.18 mm] sieve is at least 90 percent Class A, or Taconite Tailings, or both by weight.

Table 3139-10 Micro-Surfacing Gradation Limits and QC Tolerances 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
3/8 inch [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 Quality

Provide aggregate that meets the durability requirements of Table 3139-11, "Micro-Surfacing Aggregate Durability Requirements".

Table 3139-11 Micro-Surfacing Aggregate Durability Requirements		
Tests on Aggregate	Test	Requirement, %
Sand equivalent	AASHTO T 176	≥ 60
Abrasion resistance*	AASHTO T 96	≤ 30
Soundness (using MgSO4)	AASHTO T 104	≤ 25
* Use Grading C for Type 3 material. Use Grading D for Type 1 & 2 material.		
Perform the soundness test on the Class B aggregate of the blend, if applicable.		

3139.6 SAMPLING AND TESTING

Perform sampling, sieve analysis, lumps, crushing, and shale testing meeting the requirements of the MnDOT Laboratory Manual.

3145 MINERAL FILLER

3145.1 SCOPE

Provide mineral filler as a soil or mixture component.

3145.2 REQUIREMENTS

A Composition

Provide a mineral filler of carbonate dust, Portland cement, hydrated lime, crushed rock screenings¹, fly ash, or rotary kiln dust.

¹ Crushed rock needs to have a stability and durability equivalent to those of the comparable mixture containing on of the other acceptable filler materials and be free of clay and shale.

B Gradation

The mineral filler will be finer than a #4 [4.75 mm] sieve and contain less than 25% of the material passing a #200 [75µm] sieve. The portion passing the #200 [75µm] sieve will meet the following gradation².

Percent finer than 0.020 mm.....35 – 100

Percent finer than 0.005 mm.....10 – 40

Percent finer than 0.001 mm.....1 – 25

² Does not apply to Portland cement or hydrated lime

C Condition

Mineral filler which is to be added directly to the dried aggregate for the bituminous mixture will be thoroughly dry and free from lumps consisting of aggregates of fine particles. Crushed rock screenings used as mineral filler will be processed and handled in such a manner to prevent segregation and dried by passing through a dryer.

3145.2 SAMPLING AND TESTING

A Sample according to the Mn/DOT Bituminous Manual

B Fineness

B.1 Fine Aggregate Sieve Analysis according to Mn/DOT Laboratory Manual Method.... 1203

3146 B.2 Particle Size Analysis of Soil according to Mn/DOT Laboratory Manual Method..... 1302 BINDER SOIL

3146.1 SCOPE

Provide soil material for use as a binding agent for aggregate mixtures.

3146.2 REQUIREMENTS

Provide binder soil with the following characteristics:

- (1) Contains no sod, roots, plants, organics, or other deleterious material and
- (2) Contains no fly ash, incinerator ash, other manufacturing by-products or waste material.

3146.3 SAMPLING AND TESTING

A Sampling

The Engineer will sample binder soil in accordance with the Schedule of Materials Control.

B Sieve Analysis

The Engineer will perform the sieve analysis in accordance with test method 1302 of the Laboratory Manual.

3149 GRANULAR MATERIAL

3149.1 SCOPE

Provide certified granular materials along with Form G&B – 104.

3149.2 REQUIREMENTS

Use material sources meeting the requirements of 1601, "Source of Supply and Quality."

Provide certified granular material meeting the specified gradation.

Report the No. 200 sieve results to the nearest 0.1 percent and all other sieves to the nearest whole number.

Certify all granular materials on Form G&B-104, *Certification of Aggregate and Granular Materials*.

Provide certified granular material that has similar appearance, texture, moisture content, and performance characteristics.

A Granular Materials

A.1 Virgin Materials

Provide virgin aggregate meeting the following requirements:

- (1) Consists of naturally occurring mineral materials,
- (2) Contains no topsoil, organics, or severely weathered rock, and
- (3) Insoluble residue test results for the portion of quarried/bedrock carbonate aggregates, passing the No. 200 sieve is no greater than 10 percent.

A.2 Recycled Materials

For products not required to be 100% virgin, the Contractor may substitute recycled aggregates for virgin aggregates, if the recycled aggregates meet the following requirements:

- (1) Recycled aggregates consist only of recycled asphalt pavement (RAP), recycled concrete materials, and recycled aggregate materials;
- (2) The bitumen content of the blended material is no greater than 3.0 percent;

- (3) The recycled concrete material is:
 - (3.1) No greater than 75 percent of the material blend,
 - (3.2) No greater than 10 percent masonry block.

B Granular and Select Granular Borrows

Provide granular, select granular borrow, or select granular borrow (Super Sand) meeting the requirements of Table 3149-1.

Table 3149-1 Granular Borrow Gradation Ratio Requirements			
	% Passing Ratio No. 200/1 in [75 µm/25 mm]	% Passing Ratio No. 40/No. 10 [425 µm/2.0 mm]	% Passing Ratio No. 200/No. 10 [75 µm/2.0 mm]
B.1 Granular Borrow	0 – 20%	NA	NA
B.2 Select Granular Borrow	0 – 12%	NA	NA
B.3 Select Granular Borrow (Super Sand)	NA	0 – 65%	0 – 10%

C Stabilizing Aggregate

Provide stabilizing aggregate meeting the requirements of Table 3149-2 and the following.

Table 3149-2 Stabilizing Aggregate Gradation Requirements	
Sieve Size	Percent Passing
1 in [25 mm]	100
¾ in [19 mm]	90 – 100
¾ in [9.5 mm]	50 – 95
No. 4 [4.75 mm]	35 – 85
No. 10 [2.0 mm]	20 – 70
No. 40 [425 µm]	10 – 45
No. 200 [75 µm]	7 – 15.5

The minimum crushing requirement is 10 percent. Material crushed from quarries is considered crushed material.

D Backfill Materials

D.1 Granular Backfill

Provide granular backfill meeting the requirements of Table 3149-3.

Table 3149-3 Granular Backfill Requirements	
% Passing 3 in [25 mm] Sieve	100%
Percent Passing Ratio No. 200/1 in [75 µm/25 mm]	0 – 20%

D.2 Structural Backfill

Provide 100% virgin structural backfill meeting the requirements of Table 3149-4, and the following.

Table 3149-4 Structural Backfill Requirements	
% Passing ¾ in [19 mm] Sieve	100%

Table 3149-4 Structural Backfill Requirements	
Percent Passing Ratio No. 40/No. 10 [425 µm/2.00 mm]	0 – 65%
Percent Passing Ratio No. 200/No. 10 [75 µm/2.00 mm]	0 – 10%

- (1) Provide screened material meeting the requirements of 3137.2.B.3, “Classification,” for Class C.
- (2) Provide material with a minimum angle of friction (Φ) of 34° in accordance with AASHTO T 236. Perform tests on the sample portion passing the No. 10 sieve and compacted to 95 percent of Moisture Density Test Method (Proctor).

D.3 Select Granular Backfill

Provide select granular backfill meeting the requirements of Table 3149-5.

Table 3149-5 Select Granular Backfill Requirements	
% Passing 3 in [25 mm] Sieve	100%
Percent Passing Ratio No. 200/1 in [75 µm/25 mm]	0 – 12%

E Aggregate Backfill

Provide aggregate backfill meeting the requirements of Table 3149-6.

Table 3149-6 Aggregate Backfill Gradation Requirements	
Sieve Size	Percent Passing
2 in [25 mm]	100
No. 4 [4.75 mm]	35 – 100
No. 10 [2.00 mm]	20 – 70
No. 40 [425 µm]	10 – 35
No. 200 [75 µm]	3 – 10.5

F Granular Bedding

Provide granular bedding meeting the requirements of Table 3149-7.

Table 3149-7 Granular Bedding Gradation Requirements	
Sieve Size	Percent Passing
1 in [25 mm]	100
No. 200 [75 µm]	0 – 10.5

G Aggregate Bedding

Provide aggregate bedding meeting one of the following requirements:

G.1 Fine Aggregate Bedding

Provide fine aggregate bedding meeting the gradation and crushing requirements in 3138, “Aggregate for Base and Surface Courses,” for Class 5.

G.2 Coarse Aggregate Bedding

Provide 100% virgin coarse aggregate bedding meeting the requirements of Table 3149-8.

Table 3149-8	
Coarse Aggregate Bedding Gradation Requirements	
Sieve Size	Percent Passing
1½ in [37.5 mm]	100
No. 4 [4.75 mm]	0 – 10

G.3 Conduit Aggregate Bedding

Provide 100% virgin conduit aggregate bedding meeting the requirements of Table 3149-9.

Table 3149-9	
Conduit Aggregate Bedding Gradation Requirements	
Sieve Size	Percent Passing
No. 4 [4.75 mm]	100
No. 200 [75 µm]	0 – 8.5

H Coarse Filter Aggregate

Provide 100 percent virgin coarse filter aggregate excluding quarried carbonates, meeting the requirements of Table 3149-10.

Table 3149-10	
Coarse Filter Aggregate Gradation Requirements	
Sieve Size	Percent Passing
1 in [25 mm]	100
¾ in [19 mm]	85 – 100
⅜ in [9.5 mm]	30 – 60
No. 4 [4.75 mm]	0 – 10

I Blank

J Filter Aggregates

Provide filter aggregate meeting one of the following:

J.1 Medium Filter Aggregate

Provide naturally rounded and 100 percent virgin medium filter aggregate meeting the requirements of Table 3149-11 and the following.

Table 3149-11	
Medium Filter Aggregate Gradation Requirements	
Sieve Size	Percent Passing
¾ in [19 mm]	100
⅜ in [9.5 mm]	50 – 95
No. 4 [4.75 mm]	20 – 60
No. 10 [2.00 mm]	0 – 15
No. 40 [425 µm]	0 – 4
No. 200 [75 µm]	0 – 2.5

- (1) The maximum shale and soft rock content of the material retained on the No. 4 sieve is 5.0 percent.
- (2) The maximum carbonate content is 55 percent.
- (3) The maximum crushing content is 15 percent. Material crushed from quarries is considered crushed material.

J.2 Fine Filter Aggregate

Provide 100 percent virgin fine filter aggregate meeting the requirements of Table 3149-12.

Table 3149-12	
Fine Filter Aggregate Gradation Requirements	
Sieve Size	Percent Passing
$\frac{3}{8}$ in [9.5 mm]	100
No. 4 [4.75 mm]	90 – 100
No. 10 [2.00 mm]	45 – 90
No. 40 [425 μ m]	5 – 35
No. 200 [75 μ m]	0 – 3.5

K Blank

3149.3 SAMPLING AND TESTING

Sample and test at the rates specified in the Schedule of Materials Control.

A.....Sampling, Sieve Analysis, Crushing Tests and Moisture Density Test Method (Proctor)

..... Grading and Base Manual

B.....Bitumen Content Laboratory Manual Method..... 1852

C.....Insoluble Residue Laboratory Manual Method..... 1221

D.....Light Weight Pieces in Aggregate Laboratory Manual Method 1207

E.....Lithological Count Laboratory Manual Method 1209

F.....Standard Method of Test for Direct Shear Test of Soils under Consolidated Drained Conditions AASHTO T..... 236

PAVEMENT BITUMINOUS MATERIALS

3151 BITUMINOUS MATERIAL

3151.1 SCOPE

Provide bituminous materials consisting of asphalt binder, cut-back asphalt, and emulsified asphalt.

3151.2 REQUIREMENTS

Provide bituminous material from a certified source listed on the Approved/Qualified Products List meeting the following requirements for the type and grade required by the contract.

A.....Asphalt Binder

Only use Performance Grade (PG) Asphalt Binder meeting the requirements of AASHTO M 320 and the Combined State Binder Group Method of Acceptance for Asphalt Binder, available on the Asphalt Products page of the Approved/Qualified Products List.

Use asphalt binder supplier recommendations for mixing and compaction temperatures.

B.....Medium Curing Liquid Asphalt

Provide medium curing liquid asphalt meeting the requirements of AASHTO M 82. Only use cutback asphalt as approved by the Engineer.

C.....Emulsified Asphalt

Provide emulsified asphalt meeting the requirements of AASHTO M 140 for the type and grade required by the contract.

D.....Cationic Emulsified Asphalt

Provide cationic emulsified asphalt meeting the requirements of AASHTO M 208.

D.1.....Diluted CSS-1h

Provide diluted CSS-1h meeting the requirements of AASHTO M 208 with the following modifications:

- (1) Dilute the CSS-1h at a rate of one part emulsion to one part water at the place of manufacture.
- (2) Meets a distillation residue of at least 29 percent.
- (3) Saybolt viscosity, storage stability and particle charge only required on undiluted CSS-1h.

E.....Polymer Modified Cationic Emulsified Asphalt

E.1.....CRS-2P

Provide polymer-modified cationic emulsified asphalt meeting the requirements of AASHTO M 316 CRS-2P with the following modifications:

- (1) Distilled at 400 °F [204 °C] for 15 min,
- (2) Meets a residue penetration from 100 to 150 dmm,
- (3) Produced using only polymer modified base asphalt. Do not use Latex modification.

E.2.....CRS-2Pd- diluted CRS-2P

Provide diluted polymer-modified cationic emulsified asphalt meeting the requirements of AASHTO M-316 CRS-2P with the following modifications:

- (1) Distilled at 400 °F [204 °C] for 15 min,
- (2) Diluted at a rate of three parts emulsion to one part water, by volume, at the place of manufacture,

- (3) Meets a distillation residue of at least 50 percent,
- (4) Meets a residue penetration from 100 to 150 dmm,
- (5) Produced using polymer modified base asphalt. Do not use Latex modification.

- (6) Saybolt viscosity, storage stability and particle charge only required on undiluted CRS-2P.

F Polymer Modified High Float Medium Set Emulsified Asphalt HFMS-2P

Ensure that emulsified asphalt is homogenous after thorough mixing provided separation has not been caused by freezing.

Perform the polymer modification step before the emulsification process.

Provide emulsified asphalt meeting the requirements of Table 3151-1.

Table 3151-1			
HFMS-2P Emulsified Asphalt Requirements			
Test	Method	Minimum	Maximum
Tests on emulsion:			
Viscosity, Saybolt Furol at 122 °F [50 °C],	AASHTO T 59	50 s	450 s
Storage stability test*, 24 h	AASHTO T 59	—	1.0%
Sieve test	AASHTO T 59	—	0.1%
Residue by distillation	AASHTO T 59	65%	—
Oil distillate by distillation	AASHTO T 59	—	3.0%
Tests on residue from distillation:			
Penetration at 77 °F [25 °C]	AASHTO T 49	100 dmm	200 dmm
Float test, 140 °F [60 °C]	AASHTO T 50	1,200s	—
Elastic recovery, at 77 °F [25 °C]	AASHTO T 301	58%	—
* After standing undisturbed for 24 hours, ensure the surface has a smooth, homogenous color.			
AASHTO T 59 with modifications to include a 400°F ±9 °F [204°C ±5 °C] maximum temperature to be held for a period of 15 min.			

G..... Ultrathin Bonded Wearing Course (UTBWC) Polymer Modified Emulsion Membrane

Provide a polymer modified emulsion membrane meeting the requirements of

Table 3151-2:

Table 3151-2			
UTBWC Polymer Modified Emulsion Membrane Requirements			
Test	Method	Minimum	Maximum
Tests on emulsion:			
Viscosity, Saybolt Furol at 77 °F [25 °C]	AASHTO T 59	20 s	100 s
Storage stability test*, 24h	AASHTO T 59	—	1.0%
Sieve test	AASHTO T 59	—	0.05%
Residue by distillation	AASHTO T 59	63%	—
Oil distillate by distillation	AASHTO T 59	—	2.0%
Demulsibility, 12 oz [35 mL], 0.8% dioctyl sodium sulfosuccinate	AASHTO T 59	60%	—
Tests on residue from distillation:			
Penetration, at 77 °F [25 °C]	AASHTO T 49	60 dmm	150 dmm
Solubility in trichloroethylene	AASHTO T 44	97.5%	—
Elastic recovery, at 77 °F [25 °C]	AASHTO T 301	60%	—

Table 3151-2			
UTBWC Polymer Modified Emulsion Membrane Requirements			
Test	Method	Minimum	Maximum
* After standing undisturbed for 24 h, ensure the surface has a smooth, homogenous color.			
AASHTO T 59, except at no greater than 392 °F ± 9 °F [200 °C ± 5 °C] for 15 min.			

.....
H.....Micro Surfacing Emulsified Asphalt

Provide a polymer modified, CSS-1h bituminous material meeting the requirements of

Table 3151-3:

Table 3151-3		
Micro Surfacing Emulsified Asphalt Requirements		
Test	Method	Requirement
Quality on emulsion:		
Residue after distillation*	AASHTO T 59	≥ 62%
Quality on residue:		
Softening point	AASHTO T 53	≥ 135 °F [57 °C]
Penetration, at 77 °F [25 °C]	AASHTO T 49	40 – 90 dmm
Absolute Viscosity, at 140 °F [60 °C]	ASTM D 2171	≥ 8,000 P [800 Pa•s]
Solubility on base asphalt	AASHTO T 44	99%
* AASHTO T 59, except the temperature for the distillation procedure shall be held 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 cement mixing testing.		

Use minimum of 3 percent natural latex polymers or Department-approved manmade latex polymer.

3151.3 SAMPLING AND TESTING

Provide Bill of Ladings with a certification statement that the bituminous material meets the requirements in 3151.2, “Requirements.” Sample at rates and sizes meeting the requirements of the Schedule of Materials Control or as required by the contract.

The Materials Engineer will test samples submitted and certified by the manufacturer as representative of the bituminous material to be provided.

3161 ANTI-STRIPPING ADDITIVE

3161.1 SCOPE

Provide anti-stripping additives to improve the moisture sensitivity and adhesion properties between the asphalt binder and aggregate.

3161.2 REQUIREMENTS

Provide anti-stripping additives meeting the following requirements:

- (1) Composition meeting the requirements of AASHTO M 320,
- (2) Miscible with all types of bituminous materials without showing separation or settlement,
- (3) Not affecting the long term stability of the asphalt binder, and
- (4) With a concentration meeting the requirements of the Modified Lottman Test (Laboratory Manual Method 1813).

Ship and store anti-stripping additives in containers provided by the manufacturer and labeled with the following information:

- (1) Name of the manufacturer,
- (2) Trade name or trade mark,
- (3) Manufacturer's lot number,
- (4) Date of manufacture, and
- (5) Net weight of the contents.

Maintain uniform consistency from drum to drum within shipments.

3161.3 SAMPLING AND TESTING — (BLANK)

3165 ASPHALT PRIMER FOR DAMPPROOFING AND WATERPROOFING

3165.1 SCOPE

Provide asphalt primer for damp proofing and waterproofing concrete and masonry surfaces above or below ground level

3165.2 REQUIREMENTS

Provide asphalt primer meeting the requirements of ASTM D 41.

3165.3 SAMPLING AND TESTING

Provide samples at rates and sizes meeting the requirements of the Schedule of Materials Control or as required by the contract.

3166 ASPHALT FOR DAMPPROOFING AND WATERPROOFING

3166.1 SCOPE

Provide asphalt for use as a mopping coat for dampproofing or as a plying or mopping cement in the construction of a membrane system of waterproofing.

3166.2 REQUIREMENTS

Provide Type II asphalt meeting the requirements of ASTM D 449, unless otherwise required by the contract.

3166.3 SAMPLING AND TESTING

Provide samples at rates and sizes meeting the requirements of the Schedule of Materials Control or as required by the contract.

CULVERT PIPE AND SEWER PIPE

3236 REINFORCED CONCRETE PIPE

3236.1 SCOPE

Provide reinforced concrete pipe of circular, arch, elliptical, or special shape and design, with appropriate appurtenances to construct culverts, sewers, or underpasses.

3236.2 REQUIREMENTS

Provide reinforced concrete pipe meeting the following design requirements and as modified in this section:

Table 3236-1 Reinforced Concrete Pipe	
Pipe type	AASHTO reference
Circular	AASHTO M 170
Pipe-Arch	AASHTO M 206
Elliptical	AASHTO M 207

Provide concrete aprons manufactured as shown on the plans. Attach aprons compatible with pipe.

Provide concrete cattle pass units manufactured as shown on the plans and meeting the requirements of AASHTO M 170 for Class III pipe of equivalent wall thickness.

The Department will not require external load bearing tests on cattle passes and aprons.

A.....Materials

A.1.....Aggregate Quality3126 and 3137

A.2.....Form Release Agents3902

A.3.....Portland Cement3101

The Department will allow admixtures in accordance 2461, "Structural Concrete," except do not use calcium chloride.

The Department will allow the following cement substitutions:

- (1) 30 percent Class F or Class C fly ash by weight,
- (2) 35 percent ground granulated blast furnace slag by weight,
- (3) 35 percent substitution with a combination of ground granulated blast furnace slag, and
- (4) Class F or Class C fly ash by weight.

A.4.....Flyash for Use in Portland Cement Concrete.....3115

A.5.....Ground Granulated Blast Furnace Slag Cement.....3102

A.6.....Structural Concrete2461

A.7.....Metal Reinforcement2472

A.8.....Preformed Gasket Seals for Concrete Pipe3726

B.....Pipe Design

Provide pipe designed as shown on the plans or meeting the AASHTO requirements referenced in Table 3236-1, if approved as an alternate by the Engineer for the different classes of pipe meeting the following design requirements:

- (1) Pipe shape (circular, arch, elliptical),
- (2) Diameter,
- (3) Wall thickness,
- (4) Compressive strength of concrete, and
- (5) Area and type of circumferential reinforcement.

Provide pipe with reinforcement placed in accordance with applicable AASHTO Specifications referenced in Table 3236-1, except as otherwise shown on the plans or as approved by the Engineer. Do not use circular pipe with elliptical reinforcement. Lap wire mesh at least one full mesh or twenty wire diameters, whichever is greater. Do not weld laps of reinforcement for pipe unless the Engineer approves the welder, in conjunction with the Materials Engineer.

If the plans show pipes with rubber gasket seals, ensure the joint surfaces adjacent to the gasket are smooth and free of imperfections to allow the rubber gasket seal to meet the specified performance requirement.

C.....Manufacture

Provide products manufactured in a precast concrete manufacturing plant pre-approved by the Materials Engineer and listed on the Approved/Qualified Products List. Provide certified products as required by the contract from a manufacturer with production set-up on a pre-approved basis. The Engineer will limit acceptance of products to each precast concrete manufacturer and to each of the plants as pre-approved by the Materials Engineer. The Engineer, in conjunction with the Materials Engineer, will limit pre-approval to the identified sizes of circular pipe, arch pipe, elliptical pipe, and appurtenances.

Notify the Materials Engineer, before the manufacturer begins producing pipe requiring shear steel or Special Designs not listed on the Approved/Qualified Products List. Pin all shear steel.

Provide concrete units cured by the steam or water curing methods, unless using methods otherwise approved by the Materials Engineer. In all cases, use curing chambers with an atmospheric temperature no greater than 160 °F [71 °C]. Protect concrete units from freezing or drying after casting until the completion of curing.

D.....Permissible Variations

Provide pipe meeting the tolerance requirements of applicable AASHTO specifications referenced in Table 3236-1.

3236.3 SAMPLING AND TESTING

The Materials Engineer will approve each precast concrete manufacturer and its individual plants to provide precast concrete products under the pre-approval program. The Materials Engineer will not authorize precast concrete production if the manufacturer fails to abide by the terms, conditions, and requirements contained in this program.

If the Materials Engineer finds manufacturer non-compliance with the pre-approval program or evidence of non-conformance of certified products, the Materials Engineer, in conjunction with the Engineer, may perform the following:

- (1) Reject the individual product,
- (2) Reject the questioned shipment,
- (3) Reject the identified day's production, or
- (4) Revoke pre-approval privileges.

A..... Plant QC

Ensure the manufacturer establishes and implements a QC program, including the following elements for each pre-approved plant:

A.1..... Internal QC Program

Ensure the manufacturer includes the following in the internal QC program:

- (1) Sampling and testing of component materials or documentation of acceptability if materials were previously inspected and tested, or received from a certified source,
- (2) Inspection of product manufacturing including the following:
 - (2.1)..... Reinforcing steel fabrication and placement,
 - (2.2)..... Concrete mix design and proportioning,
 - (2.3)..... Concrete placement and consolidation, and
 - (2.4)..... Concrete curing.
- (3) Testing of finished products including the following:
 - (3.1)..... Strength of concrete cylinders,
 - (3.2)..... Three-edge-bearing test (round pipe), and
 - (3.3) Absorption and steel verification from pipe cores. For each class, size, and type of manufacture, on the first run of the year and as directed by the Materials Engineer, provide core specimens at least 4 in [100 mm] in diameter for the absorption test and steel verification.
- (4) Final visual inspection and stamping, and
- (5) Maintenance of plant facilities and equipment.

A.2..... On-Site Quality Control Technicians

Ensure the manufacturer employs and has on-site during production QC technicians trained and certified meeting the requirements of Mn/DOT Level I, "Concrete Field Tester" or ACI Grade I, "Quality Control Technician" to perform the following:

- (1) Ensure the conformance of all pre-approved products to the requirements,
- (2) Maintain knowledge of the following:
 - (2.1)..... Plans and specification requirements,
 - (2.2)..... Product manufacturing operations, and
 - (2.3) Significance of the specification requirements in producing quality products.
- (3) Correct, stop, or both, operations causing non-conforming attributes,
- (4) Reject products not meeting the contract requirements,
- (5) Ensure the manufacturer meets requirements related to producing pre-approved products, and
- (6) Contact the Department's inspector before making repairs greater than 10 percent of the respective surface, inside or outside.

A.3..... Equipment2461

A.4..... System of Record Keeping

Ensure the manufacturer maintains the following records:

- (1) Component material sources and passing quality test results, authorized certification, or other evidence of inspection and satisfactory testing,
- (2) Test results covering product manufacture and the finished product as listed in the records section of the ACPA manual,

- (3) Records of manufactured products in accordance with the following:
 - (3.1)..... Date,
 - (3.2)..... Size, and
 - (3.3)..... Class.
- (4) Running inventory of pre-approved products in stock, and
- (5) Equipment calibration reports.

B..... Quality Assurance

The Materials Engineer will visit each plant to perform tasks in accordance with this specification and including the following:

- (1) Random sampling and testing of the materials used in the manufacture of pre-approved products,
- (2) Random sampling and testing of the pre-approved pipe produced,
- (3) Observing the manufacturing process,
- (4) Reviewing the manufacturer’s quality control tests, inspection, records, and stockpiling practices, and
- (5) Reviewing the pre-approved product inventory.

The Engineer will perform a final inspection upon delivery.

C..... Testing Rates

C.1..... Concrete

Ensure the manufacturer tests the air content of concrete in each mix once a day for each positive slump mix.

Ensure the manufacturer tests the concrete strength of each mix meeting the requirements of “Cylinder and Core Guidelines for Precast Pipe and Box Culvert” kept on file by the Materials Engineer.

C.2..... Load Bearing Test

Ensure the manufacturer conducts Three-Edge Bearing tests meeting the requirements of AASHTO M 170, on each size and class of pipe, and in accordance with the following schedule:

Table 3236-2 Load Bearing Test Rates		
Size Range, in [mm]	Class Range	Test Rates
12 – 18 [300 – 450]	≤ 5	1 per 5,000 ft [1,500 m]
21 – 48 [525 – 1,200]	≤ 5	1 per 3,000 ft [900 m]
54 – 72 [1,350 – 1,800]	≤ 4	1 per 2,000 ft [600 m]
54 – 72 [1,350 – 1,800]	5	1 per 1,000 ft [300 m]
78 – 96 [1,950 – 2,400]	All classes	1 per 1,000 ft [300 m]
NOTE: Begin a new schedule of testing after changing the mix design, after shutting down the system for major repairs and renovations, when beginning a new production run, and when beginning a new season.		

Notify the Materials Engineer 2 full business days before testing. The Materials Engineer may select pipes for testing and may direct the manufacturer to perform additional testing at no additional cost to the Department.

Do not ship pipe that have not developed the specified D-load. Only pipe of equal or older age than a tested pipe section of the same size and class that has passed the three-edge bearing test may be shipped. Maintain documentation of all load tests performed.

D.....Pipe Marking

Provide pipe marked by the manufacturer in accordance with the following:

- (1) Meeting the marking requirements of AASHTO M 170,
- (2) Stamped with the word, "Certified,"
- (3) Stamped with the manufacturing plant identification,
- (4) For units at least 24 in [600 mm] in diameter, stamped on the inside, and
- (5) For units smaller than 24 in [600 m] in diameter, stamped on the outside.

Before stockpiling, mark products manufactured for projects with special requirements not meeting the standards of the pre-approved program with an identifying project number or the buyer's name.

The Engineer may accept pre-approved shipments if the Contractor provides pipe marked with the following by the manufacturer:

- (1) The phrase, "CERTIFIED PLANT COMPANY," in 4 in × 4 in [100 mm × 100 mm] letters,
- (2) Company identification, and
- (3) Individual production plant.

Provide the Engineer with a certified bill of materials or invoice, signed by a designated, responsible company representative with each shipment that identifies the following information:

- (1) Project number;
- (2) Contractor;
- (3) Type of material;
- (4) Number of pieces of each size, class, and length; and
- (5) The following statement:

"The materials itemized in this shipment are certified to be in compliance with the applicable Minnesota Department of Transportation Specifications and the Project Plans, including 'Buy America' provisions."

Authorized Signature and Date

Ensure the manufacturer does not ship pre-approved products until after the completion of QC tests and inspections, and as approved by the Materials Engineer.

E.....Stockpiling

Ensure the manufacturer stockpiles products meeting the above requirements to allow the Materials Engineer to inspect the products for QA, and that the manufacturer stockpiles special, non-pre-approved product in areas separate from pre-approved stock.

3238 PRECAST CONCRETE BOX CULVERTS

3238.1 SCOPE

Provide precast concrete single and multi-cell box culverts sections, headwalls, and aprons, including box culvert sections used in the as-cast position as manholes or manhole-type structures.

3238.2 REQUIREMENTS

A Fabrication Drawings, Falsework and Forms

If full construction details are not included in the plans, provide shop drawings meeting the following requirements to the Engineer for review by the Office of Bridges and Structures before fabricating the units:

- (1) Complete and comprehensive,
- (2) Include the number of mats,
- (3) Show mat makeup and configuration, and
- (4) List stirrup sizes and spacing for each type of segment as shown on the plans.

Provide precast concrete box culverts with individual sections at least 4 ft long [1.2 m] capable of being tied to the adjacent section with concrete pipe ties as specified by Mn/DOT Standard Plate 3145 and as shown on the plans. Unless specifically called for in the plans, openings in the flow line or sidewalls are not allowed.

B Materials

B.1 Concrete 2461

Provide concrete with mix designations as shown on the plans for the specific items of work.

B.2 Reinforcement Bars 3301

B.3 Steel Fabric 3303

C Forms

Provide forms capable of withstanding pressure from concrete, vibration, and impact without distorting. Set and maintain forms in a mortar tight condition, free of warp, and on a rigid foundation. Provide joints in the sectional forms without offset. Set forms to create dimensions of the precast unit as shown on the plans. Repair or replace forms not meeting the dimensions shown on the plans before casting additional sections. When recesses around lifting devices are required, use forming devices provided by the lifting device manufacturer.

Clean forms before use. Treat the face of the forms in contact with the concrete with form coating material in accordance with 3902, "Form Coating Material," before setting the forms.

D Lifting Devices and Other Steel Inserts

When lifting devices or other steel inserts will have less than 1.5 inches of concrete cover in the finished structure or if the recess is to be grouted in the field, provide items that are galvanized according to 3392.

E Reinforcement Steel

Place reinforcement steel as shown on the plans. Support reinforcement steel with chairs. Splice, secure, and tie reinforcement steel in accordance with 2472, "Metal Reinforcement." Provide concrete cover of at least 1½ in [40 mm] or as shown on the plans. Provide stainless steel, plastic, plastic tipped, hot dipped galvanized, or mechanically galvanized reinforcement supports in contact with the forms. Extend coatings on the supports at least 1 in [25 mm] from the form surface. Do not tack-weld reinforcement.

F Placement of Concrete

Do not place concrete for precast units until the Materials Engineer inspects and approves the forms and steel placement.

Place the concrete in each precast unit without interruption. Vibrate the concrete internally, externally, or both, to produce uniformly dense concrete and to avoid displacement of enclosures or steel units. Internally vibrate in accordance with 2401.3.D., "Compaction of Concrete," except provide internal vibrators with a vibrating head no greater than 1¼ in [32 mm] in diameter and capable of operating at a frequency of at least 100 Hz [6,000 impulses per min].

G Concrete Curing

Use steam or water curing methods to cure the precast concrete units unless the Materials Engineer approves the use of sealing membrane or other methods. If using elevated temperature curing, cure in accordance with 2405.3, "Prestressed Concrete Beams, Construction Requirements." If using elevated temperature curing, place the manufacturer-provided temperature recording device as directed by the Materials Engineer. Provide the Materials Engineer with the temperature records for review.

Cure until the concrete reaches a compressive strength of at least 2,500 psi [17 MPa] based on compressive strength test results from control cylinders cured with the product. The Contractor may cure control cylinders separately from the precast units if curing conditions for the cylinders are the same as for the precast units, and the control cylinders and the precast units use temperature recording devices.

H Concrete Finishing and Repair

Provide formed surfaces of the precast units with a uniform dense surface finish in accordance with 2401.3.F.2.a, "Ordinary Surface Finish." After removing the forms, examine the concrete surfaces for areas of unsound concrete and defective surfaces caused by faulty forms or form assembly, improper concrete placement, improper form removal, and other causes.

Remove and replace concrete with porosity, honeycomb, delamination, hollow sound, or segregated materials as approved by the Materials Engineer.

The Materials Engineer will not allow the following repairs in the finished product:

- (1) Individual repairs greater than 4 sq. ft [0.4 sq. m] on an inside or outside surface, and
- (2) Repairs to the tongue or groove down to the steel and greater than 4 ft [1.2 m] long.

With the approval of the Materials Engineer and in compliance with the plant quality control program, the Contractor may repair minor surface cavities or irregularities before the unit completes curing.

I Certified Plant Requirement

Provide precast concrete box culverts, end sections, and appurtenances constructed in a precast concrete fabrication plant certified by the American Concrete Pipe Association, the National Precast Concrete Association, or another organization approved by the Materials Engineer. If requested, provide quality control and plant certification records to the Materials Engineer.

3238.3 SAMPLING AND TESTING

The Materials Engineer is the Engineer with authority regarding this Specification.

The Materials Engineer will inspect the units at the plant and will stamp approved units with the official mark of the Department. Store individual units in an upright position to facilitate inspection, unless otherwise approved by the Materials Engineer. Do not ship units without the official mark of the Department. Notify the Materials Engineer at least one full business day before intent to ship. Complete finishing and repair work on units before submitting notice of intent to ship. The units are subject to final inspection of the units after delivery.

Unless otherwise directed by the Materials Engineer, mark the inside of each box section with the following information:

- (1) Project number,
- (2) Overfill height,
- (3) Segment number as shown on the plans, and
- (4) Date of manufacture.

MATERIALS AND METAL PRODUCTS

3301 REINFORCEMENT BARS

3301.1 SCOPE

Provide deformed and plain reinforcing steel for use as reinforcement in concrete construction.

3301.2 REQUIREMENTS

Provide reinforcement bars, other than wire, meeting the requirements of the following AASHTO specifications for the size, type and grade as shown on the plans or as required by the contract:

Table 3301-1 AASHTO Specifications Per Bar Type	
Reinforcement Bars	AASHTO Specification Requirement
Billet steel bars	AASHTO M 31
Rail steel bars	AASHTO M 322 M/AASHTO M 322
Axle steel bars	AASHTO M 322 M/AASHTO M 322

If the plans or specifications do not specify the type or grade of reinforcement bars, provide Grade 60 [Grade 420] of any type except as modified by the following:

- (1) Provide deformed billet steel reinforcement bars for use in a concrete bridges, including precast units, box culverts, and retaining walls.
- (2) Provide deformed reinforcement bars of any type or grade for use in all other concrete structures, and
- (3) If required or allowed by the contract, weld bars meeting the requirements of ASTM A 706 and having a yield point of at least 60,000 psi [414 MPa].

If required in the plans, provide epoxy coated reinforcement bars meeting the requirements of AASHTO M 284. Apply the coating in a fusion bonded epoxy coating plant certified by the CRSI.

Ensure the plant's quality control office maintains documentation required by CRSI certification, including test data and measurements taken at times and locations as directed by the Materials Engineer.

Fabricate, store, and place reinforcement in accordance 2472, "Metal Reinforcement."

3301.3 SAMPLING AND TESTING

Sample and test reinforcement bars in accordance with the Schedule of Materials Control. If the Materials Engineer determines that the fusion bonded epoxy coating plant is not following approved coating procedures, correct the process and repair or replace the unacceptable material as directed by the Materials Engineer.

3302 DOWEL BARS

3302.1 SCOPE

Provide dowel bars for use in portland cement concrete pavements and other concrete applications as shown on the plans.

3302.2 REQUIREMENTS

Provide Grade 40 or Grade 60 steel dowel bars meeting the requirements of AASHTO M 31. Provide an epoxy coating meeting the requirements of AASHTO M 254. Epoxy coat the ends of the dowel bars as required by the manufacturer. Apply epoxy coating in a fusion bonded epoxy coating plant certified by the CRSI or another organization approved by the Materials Engineer. Use alternate dowel bar materials as required by the contract.

Ensure the manufacturer's plant quality control office maintains documentation containing the data required by certification, including test data and measurements taken at times and locations as required by the CRSI, the Materials Engineer, or both.

Store and protect dowel bars as specified in 2472, "Metal Reinforcement."

The Contractor may perform shearing if the epoxy coating is not damaged and subject to permissible deformation. The Engineer will ensure dowel bars do not contain deformations greater than the true shape by 0.04 in [1 mm] in diameter or thickness, or extend greater than 0.40 in [10 mm] from the dowel end.

3302.3 SAMPLING AND TESTING

Sample and test dowel bars in accordance with the Schedule of Materials Control.

3303 STEEL FABRIC

3303.1 SCOPE

Provide steel fabric for use as concrete reinforcement.

3303.2 REQUIREMENTS

Provide steel fabric for concrete reinforcement meeting the requirements of AASHTO M 55 or AASHTO M 221 for plain or deformed wire, except the Contractor may use oversized wire. If the Contractor uses oversize wire, the maximum and minimum diameter requirements will not apply. Provide flat sheets or rolls of fabric.

3303.3 SAMPLING AND TESTING

Sample and test the steel fabric in accordance with the Schedule of Materials Control.

3305 SPIRAL REINFORCEMENT

3305.1 SCOPE

Provide steel wire for use as spiral cage reinforcement for round columns.

3305.2 REQUIREMENTS

Provide cold drawn steel wire to fabricate spiral cage reinforcement for round columns meeting the requirements of AASHTO M 32 for the size shown on the plans. Alternatively, the Contractor may use plain or deformed Grade 60 billet steel bars in accordance with 3301, "Reinforcement Bars."

When required to splice spiral reinforcement by welding, perform welding in accordance with the requirements of ANSI/AWS D1.4, "Structural Welding Code - Reinforcing Steel."

3305.2 SAMPLING AND TESTING

Sample and test in accordance with the requirements of 3301, "Reinforcement Bars."

3376 FENCE WIRE

3376.1 SCOPE

Provide barbed, woven, and chain link fencing wire, wire fasteners, tie wires, hardware, and tension wire.

3376.2 REQUIREMENTS

A..... Barbed Wire

Provide 4 point, full round barbs at least 0.375 in [9.5 mm] long. The Contractor may provide one of the following types of barbed wire, meeting the requirements of AASHTO M 280, unless the contract requires otherwise:

- (1) Zinc-coated barbed wire meeting the requirements of Class 3,
- (2) Standard security grade aluminum-coated barbed wire, or
- (3) High security grade aluminum-coated barbed wire.

B..... Woven Wire

Provide metallic-coated, Type A or Type Z Class 3 steel woven wire fence fabric meeting the requirements of AASHTO M 279, for the size and construction required by the contract.

Provide No. 9 Grade 60 design woven wire fabric meeting the requirements of AASHTO M 279 if the contract does not specify the size and construction.

Use the hinge joint method with at least 1½ tightly wrapped twists to join the vertical stay wires to each horizontal line wire.

C..... Chain Link

Provide chain link fabric meeting the requirements of AASHTO M 181 for the type required by the contract. Use chain link fence with the finished wire size, mesh size, selvage type, and fabric height as shown on the plans. Use Class A extruded and bonded or Class B bonded Type IV fabric, PVC coated steel.

D..... Miscellaneous Items

Provide hardware items meeting the requirements of AASHTO M 181 unless otherwise specified in this section or required by the contract.

Use L-shaped staples with barbed, serrated, or ring shanks or U-shaped staples made of 9 gauge [3.8 mm] diameter wire galvanized after fabrication meeting the requirements of ASTM A 153 to attach wire to wood posts with shank length as specified in 2557.3.C.2, "Barbed Wire and Woven Wire.

Use flat metal bands instead of wire fasteners if approved by the Engineer.

Provide hog rings meeting the requirements of ASTM F 626. When polymer coating is required, provide hog rings with a Class 2A or Class 2B polymer coating thickness meeting the requirements of ASTM F 668.

Provide wire ties meeting one of the following requirements:

- (1) 9 gauge steel meeting the requirements of AASHTO M 181, or
- (2) At least 0.179 in [4.55 mm] aluminum alloy meeting the requirements of ASTM B 211, Alloy 1100 H18.

Provide polymer-coated wire ties meeting the same coating thickness requirements as polymer-coated fabric.

Provide tension wire meeting the requirements of AASHTO M 181.

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Provide tension bars, truss rods, truss rod tighteners, barbed wire arms, tension bands, brace bands, rail and brace ends, rail sleeves, post and line caps, and cups meeting the requirements of AASHTO M 181.

Provide polymer-coated tension bars, truss rods, truss rod tighteners, tension bands, brace bands, post and line caps, and cups with a bonded polymer coating thickness of at least 0.010 in [0.25 mm].

Provide zinc coated nuts and bolts meeting the requirements of AASHTO M 232. Shop-paint or field-paint nuts and bolts when polymer-coated fence is required.

3376.3 SAMPLING AND TESTING

Submit to the Engineer a manufacturer's Certificate of Compliance for each fence component in this section including Buy America compliance, if required.

Sample and test in accordance with the Schedule of Materials Control.

3379 FENCE GATES

3379.1 SCOPE

Provide vehicular gates and pedestrian gates with pipe frames.

3379.2 REQUIREMENTS

A..... General

Use the same pipe, hardware, fittings, fence wire, and appurtenance materials to assemble all gates provided to the project.

B..... Materials

Use a frame made of galvanized steel pipe or aluminum alloy pipe.

B1..... Galvanized Steel Pipe

Provide galvanized steel pipe meeting the requirements of ASTM A 53 for galvanized Standard Schedule 40 pipe with plain ends. Hydrostatic testing of the pipe is not required.

B2..... Aluminum Alloy Pipe

Provide aluminum alloy pipe meeting the requirements of AASHTO M 181.

B3..... Fittings and Hardware

As shown on the plans, use corner fittings, tops, stretcher bars, truss rods, and other required fittings, hardware, and appurtenances made of steel, malleable iron, wrought iron, or aluminum alloy. If using steel or iron, galvanize fittings or hardware in accordance with AASHTO M 181 after fabrication.

B4..... Wire

Provide barbed wire, gate fabric for woven wire fence, and gate fabric for chain link fence as specified in 3376, "Fence Wire."

C..... Physical Properties

Use gate and members with physical properties as shown on the plans.

Use fittings, hardware, and other required appurtenances capable of being securely fastened and fitted to meet the requirements of the approved design.

Provide hinges and catch and locking devices meeting the requirements of an approved design.

3379.3 SAMPLING AND TESTING

Submit to the Engineer a manufacturer's Certificate of Compliance for each component in this section including Buy America compliance, if required.

Sample and test in accordance with the Schedule of Materials Control.

A.....Metal Pipe and Fittings	3406
B.....Fence Wire and Fasteners.....	3376

3392 GALVANIZED HARDWARE

3392.1 SCOPE

Provide galvanized hardware as specified in the contract.

3392.2 REQUIREMENTS

Provide galvanized hardware and miscellaneous items as shown on the plans. Galvanize hardware items using the hot-dip process meeting the requirements of with ASTM A 153, or mechanically galvanize the hardware meeting the requirements of ASTM B 695, Class 50, Type I.

3392.3 SAMPLING AND TESTING

Sample and test in accordance with the requirements of the Schedule of Materials Control.

POSTS

3403 HOT-ROLLED STEEL FENCE POSTS

3403.1 SCOPE

Provide hot-rolled steel posts and angles for fencing.

3403.2 REQUIREMENTS

Provide hot-rolled steel line posts and angle section post assemblies for end, gate, corner, or intermediate brace assemblies meeting the requirements of ASTM A 702 and as shown on the plans.

3403.3 SAMPLING AND TESTING

Submit to the Engineer a manufacturer's Certificate of Compliance and a certified mill analysis showing the chemical composition of each delivered lot or heat of posts and compliance with Buy America, if required.

Sample and test in accordance with the Schedule of Materials Control. The Engineer may take samples for testing from any of the provided posts.

3406 STRUCTURAL METAL FENCE POSTS

3406.1 SCOPE

Provide tubular metal posts and rails, metal rolled-formed "C" posts, and fittings for fencing.

3406.2 REQUIREMENTS

A.....Materials

Provide posts and rails meeting the requirements of AASHTO M 181, except as noted. Use Grade 1 round posts.

For Alternate Roll Formed posts, provide posts meeting the weight and property requirements of ASTM F 1043 for Heavy Industrial Fence Framework Grade 50 with Type A coating.

Use line posts weighing 2.40 lb per ft [3.6 kg per m] nominal.

Use brace bars weighing 1.35 lb per ft [2.0 kg per m] nominal.

Apply coatings on posts, rails, and fittings after welding and fabrication. Provide tie wires, clips, and bands for fastening chain link fabric to posts, rails, and braces as specified in 3376, "Fence Wire." Use Type IV (PVC) posts, rails, and frames first coated with zinc and then coated with PVC Class B bonded to a thickness of at least 0.010 in [250 µm].

B.....Dimensions

Provide posts, rails, and stretcher bars required by the contract meeting the requirements of AASHTO M 181, except the Engineer will not accept posts greater than 1 in [25 mm] shorter than the specified length.

Use fittings and hardware to fit securely over the posts.

3406.3 SAMPLING AND TESTING

Submit to the Engineer a manufacturer's Certificate of Compliance and a certified mill analysis showing the chemical composition of each delivered lot or heat of posts and compliance with Buy America, if required.

Sample and test in accordance with the Schedule of Materials Control. The Engineer may take samples for testing from any of the provided posts.

3412 WOOD GUARDRAIL POSTS

3412.1 SCOPE

Provide preservative treated wood posts for use in guardrail construction, including round posts and sawed timber posts with rectangular cross sections and offset blocks.

3412.2 REQUIREMENTS

A..... Round Posts

A.1..... Species of Wood

Provide treated round posts made from the following species of wood:

- (1) Northern White Cedar,
- (2) Western Red Cedar,
- (3) Jack Pine,
- (4) Norway (Red) Pine,
- (5) Lodgepole Pine,
- (6) Ponderosa Pine, or
- (7) Southern (Yellow) Pine.

A.2..... Seasoning

Air-season wood for treated posts. The wood may be conditioned as part of the treating process for penetration of preservative without damage to the posts.

A.3..... Dimensions and Finish

Provide naturally round posts. Shave off inner bark and closely trim knots.

Saw the bottom end of the posts square. Provide posts in the length, nominal diameter, and with a top finish as shown on the plans.

Complete debarking, trimming, and sizing of posts before applying the preservative treatment.

A.4..... Quality

Do not use wood with the following defects:

- (1) Unsound and unsmooth knots that impair the post strength,
- (2) Short kinks, defined by a line drawn between centers of the butt and tip falling outside the center of the post by more than 2 percent of the post length,
- (3) Checks wider than ¼ in [6 mm],
- (4) Unsightly and exaggerated winding twists,
- (5) Decay, except Northern White Cedar may contain one pipe rot no greater than ¾ in [10 mm] in diameter in the top of the post,
- (6) Butt rot and ring rot totaling greater than 5 percent of the butt area in Northern White Cedar,
- (7) Defects that affect the appearance or impair the strength or durability of the post as determined by the Engineer, and
- (8) One-way sweep greater than 2 in [50 mm].

B..... Sawed Timber Posts

B.1.....Species and Grade

Provide sawed timber posts made from the following species of wood:

- (1) Douglas Fir,
- (2) Southern (Yellow) Pine,
- (3) Jack Pine,
- (4) Norway (Red) Pine, or
- (5) Ponderosa Pine.

Provide sawed timber posts in the grade meeting

Provide sawed timber posts in the grade meeting the following requirements and characteristics:

- (1) Stained sapwood,
- (2) Splits $\frac{3}{4}$ of the thickness,
- (3) Seasoning checks, single or opposite each other, with a sum total depth equal to half of the post thickness,
- (4) Heavy torn grain,
- (5) Close grain,
- (6) Slope of grain over the full length of post no greater than 1 in 12,
- (7) Pitch streaks with medium pitch pockets,
- (8) Wane $\frac{1}{8}$ of any face,
- (9) Shakes $\frac{1}{3}$ of the thickness, and
- (10) Well-spaced, sound, and tight knots no wider than the following:
 - (10.1)..... $1\frac{3}{16}$ in [30 mm] in 5 in [130 mm] posts,
 - (10.2)..... $1\frac{1}{2}$ in [40 mm] in 6 in [150 mm] posts, and
 - (10.3)..... 2 in [50 mm] in 8 in [200 mm] posts.

For rectangular post sizes, use the wider face to determine the maximum size of the knots permitted.

B.2.....Dimensions

Saw the posts and offset blocks to the nominal dimensions as shown on the plans. The Engineer will not require surfacing. Do not allow the sawing dimensions for dry material to vary from the nominal dimensions by greater than $-\frac{1}{4}$ in [6 mm] or $+\frac{1}{2}$ in [13 mm].

C.....Preservative Treatment

Treat posts and offset blocks in accordance with 3491, "Preservatives and Preservative Treatment of Timber Products." Provide treated posts and offset blocks with a dry surface and free of excess preservative.

3412.3 SAMPLING AND TESTING.....3491

3413 WOOD FENCE POSTS (TREATED)

3413.1 SCOPE

Provide preservative treated wood posts for fence construction.

3413.2 REQUIREMENTS

A.....Species of Wood

Provide posts cut from live, growing trees and made from Northern White Cedar or any species of Pine, except Lodgepole Pine.

B.....Seasoning

Air-season or otherwise condition wood posts to allow penetration of the preservative.

C.....Manufacture

C.1.....Peeling

Shave off inner bark and closely trim knots before treating.

C.2.....End Finish

Cut the ends of posts square. If setting the post by driving, the Contractor may cut the larger end to a blunt point with a length no greater than 1½ times the diameter of the pointed end.

C.3.....Dimensions

Provide naturally round posts in the length and minimum diameter as required by the contract. The Contractor may provide posts with a diameter at the small end no greater than 2 in [50 mm] greater than the minimum diameter required by the contract.

C.4.....Quality

Do not use wood with the following defects:

- (1) Knots that impair the post strength,
- (2) Short kinks, defined by a line drawn between centers of the butt and tip falling outside the center of the post by more than 2 percent of the post length,
- (3) Checks wider than ¼ in [6 mm],
- (4) Unsightly and exaggerated winding twists,
- (5) Decay, except Northern White Cedar may contain one pipe rot no greater than ¼ in [6 mm] in diameter,
- (6) Butt rot and ring rot totaling greater than 5 percent of the butt area in Northern White Cedar, and
- (7) Defects that affect the appearance or impair the strength or durability of the post as determined by the Engineer.

D.....Preservative Treatment

Treat posts in accordance with 3491, "Preservatives and Preservative Treatment of Timber Products."

Cut, trim, and point ends before treatment.

Provide treated posts with a dry surface and free from dripping or excess preservative.

3413.3 SAMPLING AND TESTING.....3491

PAINTS AND ENAMELS

3501 BASIC REQUIREMENTS FOR PAINTS

3501.1 SCOPE

Provide paints for construction and maintenance.

3501.2 REQUIREMENTS

A..... Package Stability

Ensure the paint does not cake, liver, thicken, curdle, gel, or show other objectionable properties that cannot be corrected by stirring during 6 months after delivery.

B..... Colors

Provide paint matching the Federal Standard 595 colors or the Department's standard colors required by the Contract. The Department's standard colors are located at the Materials Laboratory. A paint color is considered to match the specified Standard if $\Delta E \leq 3.0$ when measured according to ASTM D 2244.

C..... Toxic Metals and Volatile Organic Compounds (VOC)

Provide paints free of toxic metals and meeting the requirements of Federal and MPCA VOC regulations.

D..... Manufacturing and Packaging

Screen paint while filling containers to remove coarse particles and skins.

Package the paint in new containers marked with the following information:

- (1) Name of the manufacturer,
- (2) Name of contents,
- (3) Specification number,
- (4) Date, and
- (5) Manufacturer's batch number.

Provide paint in quantities based on the volume or unit mass at 77° F [25° C].

E..... Drying Time

Ensure drying time for paint meets the requirements of the contract.

F..... Approval Process

Obtain approval of the paint from the Engineer before use, unless the contract requires the paint selection or it appears on the on the Approved Products List.

3501.3 SAMPLING AND TESTING

Provide samples at rates and sizes meeting the requirements of the Schedule of Materials Control or as required by the contract.

Provide a color Draw Down sample on a Leneta chart per ASTM D 2805 to the Materials Laboratory for verification of the finish coat color.

3520 ZINC-RICH PAINT SYSTEMS

3520.1 SCOPE

Provide zinc-rich paint systems.

3520.2 REQUIREMENTS3501

A..... Zinc-Rich Primer

Provide multi-component zinc-rich primer capable of being spray-applied in accordance with the manufacturer's instructions and applications guide. After mixing according to the manufacturer's recommendation, strain the primer through a 30-60 mesh screen or a double layer of cheesecloth to remove un-dispersed zinc agglomerates. Formulate the primer to produce a distinct contrast with blast cleaned steel and with the subsequent intermediate coat.

A.2..... Pigment

Provide a metallic zinc pigment meeting the requirements of ASTM D 520. Only add inert materials to the pigment for tinting. Ensure the inert materials do not reduce the effectiveness of the galvanic protection.

A.3..... Finished Primer

Provide finished primer meeting the requirements in Table 3520-1:

Table 3520-1 Finished Primer Requirements	
Characteristic	Requirement
Zinc portion, total solids by weight	≥ 75.0 %
Pot life at 77° F [25° C]	≥ 4 h
Density of VOC	≤ 3.5 lb/gal [420 g/L]
Slip coefficient of cured primer	≥0.33
Cure time for recoating*	per Manufacturer's Product Data Sheet
* When applied at 3 mil [74 μm] dry-film thickness at 77° F [25° C] and 50 percent R.H.	

B..... Approved Epoxy Zinc-Rich Systems

Provide a zinc-rich paint system listed on the Approved Products List for "Bridge Structural Steel Coatings."

B.1..... Epoxy Zinc-Rich System

Provide an epoxy zinc-rich system consisting of an epoxy zinc-rich primer, an epoxy intermediate coat, and an aliphatic urethane finish coat.

B.2..... Inorganic Zinc-Rich System

Provide an inorganic zinc-rich system consisting of solvent-based inorganic zinc-rich primer, an epoxy intermediate coat, and an aliphatic urethane finish coat.

B.3..... Moisture-Cure Zinc-Rich System

Provide a moisture-cure zinc-rich system consisting of moisture-cure zinc-rich primer, a urethane intermediate coat, and an aliphatic urethane finish coat.

B.4..... Two Coat Zinc-Rich System

Provide a moisture cure zinc-rich system consisting of moisture-cure zinc-rich primer and a fast-dry polyaspartic urethane finish coat.

C..... Color

Provide a semi-gloss finish coat as required by the contract.

D..... Packaging and Labeling

Provide multi-component paints packaged in separate containers or kits that ensure paint manufacturer's mixing proportions are achieved when using the entire container.

3520.3 SAMPLING AND TESTING

Provide to the Engineer a manufacturer's Certificate of Compliance with each batch, lot, or both for each component of the zinc-rich paint system.

Provide a color Draw Down sample on a Leneta chart per ASTM D 2805 to the Materials Laboratory for verification of the finish coat color.

3532 EXTERIOR POLYURETHANE PAINT

3532.1 SCOPE

Provide exterior polyurethane finish paint for use on steel lighting cabinets, signs, handrails, traffic signal poles and transformer bases.

3532.2 REQUIREMENTS.....3501

Provide paint free of toxic metals and meeting the requirements of Federal and MPCA VOC regulations.

Provide an aliphatic polyurethane finish coat listed on the Approved Products List for "Traffic Signal Paint Systems."

Use the finish coat with an intermediate coat or primer and intermediate coat from the same manufacturer.

A..... Color

Provide the following semi-gloss finish coat in colors chosen from the Federal Standard 595C colors unless otherwise required by the contract:

- (1) Dark green: Federal Standard Number 595C Color Number 14062, and
- (2) Yellow: Federal Standard Number 595C Color Number 13538.

3532.3 SAMPLING AND TESTING3501

Sample at rates and sizes meeting the requirements of the Schedule of Materials Control or as required by the contract.

Provide a color Draw Down sample on a Leneta chart per ASTM D 2805 to the Materials Laboratory for verification of the finish coat color.

3533 ALUMINUM POLYURETHANE PAINT

3533.1 SCOPE

Provide aluminum-filled polyurethane paint for use as a finish coat on bridges, sign posts, traffic signal poles, and luminaire extensions.

3533.2 REQUIREMENTS.....	3501
Provide paints free of toxic metals and meeting the requirements of Federal and MPCA VOC regulations.	

Provide an aluminum polyurethane paint listed on the Approved Products List for Traffic Signal Paint Systems.

Use the finish coat with an intermediate coat or primer and intermediate coat from the same manufacturer.

3533.3 SAMPLING AND TESTING.....3501

Sample at the rates and sizes meeting the requirements of the Schedule of Materials Control or as required by the contract.

Provide a color Draw Down sample on a Leneta chart per ASTM D 2805 to the Materials Laboratory for verification of the finish coat color.

3584 EXTERIOR MASONRY ACRYLIC EMULSION PAINT

3584.1 SCOPE

Provide acrylic latex paint for coating exterior masonry.

3584.2 REQUIREMENTS.....3501

Provide paints free of toxic metals and meeting the requirements of Federal and MPCA VOC regulations.

Provide acrylic latex paint listed on the Approved Products List, meeting the requirements of Federal Specification TT-P-19, and having a vehicle consisting of 100 percent straight acrylic polymer.

Provide paint in the color required by the contract. Only use light fast colorants.

3584.3 SAMPLING AND TESTING.....3501

Sample at the rates and sizes meeting the requirements of the Schedule of Materials Control or as required by the contract.

Provide a color Draw Down sample on a Leneta chart per ASTM D 2805 to the Materials Laboratory for verification of the finish coat color.

STONE AND BRICK

3613 BUILDING BRICK (CLAY OR SHALE)

3613.1 SCOPE

Provide clay or shale building brick for use in the construction of transportation facilities

3613.2 REQUIREMENTS

Provide clay or shale building brick meeting the requirements of AASHTO M 114. Provide grade SW, unless otherwise required by the contract.

3613.3 SAMPLING AND TESTING

Sample and test in accordance with the Schedule of Materials Control.

3614 BUILDING BRICK (SAND-LIME)

3614.1 SCOPE

Provide sand-lime building brick for use in the construction of transportation facilities.

3614.2 REQUIREMENTS

Provide sand-lime building brick meeting the requirements of ASTM C 73. If the contract does not require a specific brick grade, provide grade MW building brick.

3614.3 SAMPLING AND TESTING

Sample and test in accordance with the Schedule of Materials Control.

3615 BUILDING BRICK (CONCRETE)

3615.1 SCOPE

Provide concrete building brick for construction.

3615.2 REQUIREMENTS

Provide concrete building brick meeting the requirements of ASTM C 55.

3615.3 SAMPLING AND TESTING

Sample and test in accordance with the Schedule of Materials Control.

3616 SEWER BRICK (CONCRETE)

3616.1 SCOPE

Provide concrete brick to construct catch basins and manholes.

3616.2 REQUIREMENTS

Provide concrete brick meeting the requirements of ASTM C 139, as modified by the following:

- (1) Provide concrete brick with a compressive strength of at least 4,100 psi [28 MPa] for any individual unit and an average compressive strength of 4,500 psi [31 MPa] for three units, when delivered to the project, and
- (2) Use steam or water curing methods to cure the concrete, unless the Materials Engineer approves the use of a sealing membrane or other curing methods. If steam curing, maintain an atmospheric temperature in the curing chamber no greater than 158 °F [70 °C]. Protect the concrete from freezing until the completion of curing. Continue curing until the concrete develops the compressive strength shown above in item (1) within 28 days.

Use any standard size brick capable of producing the dimensions in the completed structure as shown on the plans.

3616.3 SAMPLING AND TESTING.....ASTM C 140

PRECAST CONCRETE UNITS

3621 CONCRETE MASONRY UNITS

3621.1 SCOPE

Provide solid, precast, segmental concrete masonry units to construct catch basins and manholes.

3621.2 REQUIREMENTS

Provide concrete masonry units in accordance with 3616.2, "Sewer Brick (Concrete), Requirements," modified to provide units with dimensions as shown on the plans and with wall thicknesses of 8 in $\pm\frac{3}{8}$ in [200 mm \pm 10 mm].

3621.3 SAMPLING AND TESTING.....3616

3622 SECTIONAL CONCRETE MANHOLE AND CATCH BASIN UNITS

3622.1 SCOPE

Provide precast, reinforced concrete manhole/catch basin units consisting of riser sections and appurtenances such as grade rings, base slabs, tops, and special sections to construct sewer or water works.

3622.2 REQUIREMENTS

Provide reinforced concrete manhole/catch basin units meeting the requirements of AASHTO M 199, 3236, "Reinforced Concrete Pipe," and the following.

Notify the Materials Engineer a minimum of 2 weeks before the manufacturer starts production to arrange for inspection.

A Physical Properties

Provide sectional concrete manhole/catch basin units in the dimensions, shape, wall thickness, type, and quantity of reinforcement as shown on the plans.

The Contractor may use alternative spigot-up joint or alternative offset joint. Use the profile or pre-lubricated pipe seal system with the alternative offset joint.

Ensure test results show a compressive strength of at least 4,200 psi [28 MPa] at 28 calendar days and before shipping the product to the project site.

B Manufacture

Provide units true to shape and with smooth, dense surfaces uniform in appearance. As soon as the forms are removed, use mortar to fill minor surface cavities or irregularities not impairing the service value of the unit and capable of being corrected without marring the appearance. Remove forms without damaging the unit.

When the manufacturer provides manholes with block outs or holes, provide additional steel in the remaining unit to prevent cracking. If the unit is cracked, remove the cracked portion and repair with mortar in accordance with the approved repair procedure in the QM Manual and notify the MnDOT inspector for acceptance.

When manufacturing special design rectangular manholes, provide sections meeting the manufacturing requirements of 3238.

3622.3 SAMPLING AND TESTING.....3236

3630 PRECAST CONCRETE MEDIAN BARRIERS

3630.1 SCOPE

Provide precast concrete median barriers for use in construction work zones.

3630.2 REQUIREMENTS 3238

Provide precast concrete median barriers manufactured at a precasting plant approved by the Materials Engineer.

A..... Materials

A.1..... Concrete.....2461

A.2..... Mix Designation2533

A.3..... Reinforcement Bars3301

B..... Concrete Finish

If shown on the Plans or required by the Special Provisions, sandblast the precast barrier units and fill the surface imperfections with a grout-containing bonding agent in accordance with 2401.3.F.2.a, "Ordinary Surface Finish." Begin sandblasting and grouting operations after stripping the forms and while the concrete barriers are still warm.

3630.3 SAMPLING AND TESTING.....3236

JOINT FILLERS AND SEALERS

3702 PREFORMED JOINT FILLERS

3702.1 SCOPE

Provide preformed filler material for joints in concrete construction.

3702.2 REQUIREMENTS

Use preformed joint filler material meeting the requirements of AASHTO M 153 or AASHTO M 213.

Provide the filler for each joint in a single piece for the full depth and width required for the joint unless otherwise approved by the Engineer. For pavement construction, provide filler in lengths equal to the width of the pavement lanes. Where dowel bars are necessary, provide joint filler with properly sized clean-cut punched holes correctly spaced to fit flush with the dowel bars.

Provide fiber or granulated cork bituminous bound-type filler meeting the requirements of AASHTO M 213, unless otherwise required by the contract or approved by the Engineer.

3702.3 SAMPLING AND TESTING — (BLANK)

3719 HOT-POURED, CRUMB-RUBBER TYPE CRACK SEALER

3719.1 SCOPE

Provide hot-poured, crumb-rubber type crack sealer for sealing cracks in concrete and bituminous pavements and miscellaneous structures.

3719.2 REQUIREMENTS

Provide crack sealer material meeting the following requirements:

- (1) On the Approved Products List,
- (2) Consists of asphalt and crumb rubber blended together by the manufacturer to produce a homogeneous mixture,
- (3) When melted, the sealer does not separate or settle, and
- (4) Uniform consistency suitable for filling joints and cracks without inclusion of large air holes or discontinuities.

A.....Physical Requirements

Provide crack sealer meeting the requirements of ASTM D 6690, Type I with the following modifications in Table 3719-1 after one cycle of heating to the manufacturer's maximum heating temperature, cooling, and reheating to the manufacturer's maximum heating temperature.

Table 3719-1 ASTM D 6690, Type I Modifications	
Test	Specification
Recycled rubber, mass	≥ 18% of asphaltic components
Bond Test, 50% extension at 0° F [-18° C]*	No adhesion or cohesion bond failure after 5 cycles
Resilience at 77° F [25° C]	≥ 40%
Softening point	≥ 180 °F [82° C]
*Use sawed cement mortar blocks or asphalt HMA blocks prepared using the method found in the Mn/DOT Laboratory Manual.	

BPackaging and Marking

Package and ship the sealer material in boxes weighing no greater than 50 lb [23 kg]. Mark the boxes with the following information:

- (1) Material name,
- (2) Manufacturer name,
- (3) Brand name,
- (4) Weight,
- (5) Batch number, and
- (6) Maximum heating temperature recommended by the manufacturer.

3719.3 SAMPLING AND TESTING

ASampling

Provide samples at rates and sizes meeting the requirements of the Schedule of Materials Control or as required by the contract.

The Materials Engineer will perform tests on samples taken from the product proposed for use. Submit to the Engineer a manufacturer's Certificate of Compliance for each sealer batch.

BMethods of Test

Perform tests meeting the requirements of ASTM D 5329, except, perform the bond test using sawed cement mortar blocks or asphalt HMA blocks (consistent with the pavement type) prepared in accordance with the methods in the Laboratory Manual.

3721 PREFORMED ELASTOMERIC COMPRESSION JOINT SEALS FOR CONCRETE

3721.1 SCOPE

Provide preformed polychloroprene elastomeric joint seals for use in sealing joints in concrete pavements, bridges, and other structures.

3721.2 REQUIREMENTS

AComposition and Manufacture

Provide joint seals meeting the requirements of ASTM D 2628 and as specified in this section.

Provide seals that are preformed and manufactured from a vulcanized elastomeric compound using polymerized chloroprene as the only polymer.

BSize and Shape

Provide preformed elastomeric compression joint seals in the size, shape, and dimensional tolerances of the seals as shown on the plans or required by the contract. The Contractor may use alternate shapes, if approved by the Engineer.

CPhysical Properties

Unless the contract requires otherwise, provide a ¹³/₁₆ in [20 mm] joint seal meeting the physical properties in accordance with ASTM D 2628 and the following table:

Table 3721-1	
¹³/₁₆ in [20 mm] Joint Seal Compression-Deflection Requirements	
Property	Requirement
Force at 0.65 in [16.5 mm]*	≥ 4 lb/linear inch [0.70 N/mm]
Force at 0.41 in [10.5 mm]*	≤ 20 lb/linear inch [3.50 N/mm]
* Meeting the requirements of ASTM D 2628 and the Compression-Deflection Test Method located in the Laboratory Manual.	

DIdentification and Marking

Provide joint seals marked with the following at intervals no greater than 4 ft [1.2 m]:

- (1) Manufacturer's name or the manufacturer's trademark,
- (2) Lot number, and
- (3) Date of production.

For multiple die extrusion machines, identify the seal produced from each extrusion die as an individual subplot, in addition to the list above. Limit individual lot numbers or subplot numbers to one every 8 h shift or every 6,000 ft [1,800 m], whichever results in the smallest lot size. Place a mark on the top surface of the seal at 1 ft [300 mm] intervals, to allow length measurements on each seal after installation.

Provide containers to package joint seals for shipment marked with the following information:

- (1) Name of the manufacturer,
- (2) Lot number or subplot number, and
- (3) Date of manufacture.

E.....Lubricant-Adhesive

Provide lubricant-adhesive meeting the requirements of ASTM D 2835 to install the seals.

3721.3 SAMPLING AND TESTING

The Engineer in conjunction with the Materials Engineer may sample and test joint seals and lubricant adhesive materials before or after delivery.

The Engineer in conjunction with the Materials Engineer may reject an entire lot or subplot if a test result for that lot or subplot fails.

A.....Sampling

Provide samples at rates and sizes meeting the requirements of the Schedule for Materials Control or as required by the contract.

B.....Sample Preparation

The Materials Engineer will prepare test specimens meeting the requirements of ASTM D 2628 and in accordance with the Laboratory Manual.

C.....Compression Deflection Test

Perform compression deflection testing on two specimens in accordance with the Laboratory Manual.

3722 SILICONE JOINT SEALANT

3722.1 SCOPE

Provide a silicone joint sealant for use in concrete pavement joints and cracks to protect the pavement from intrusion of water and incompressible material.

3722.2 REQUIREMENTS

Provide silicone joint sealant meeting the requirements of ASTM D 5893 and the following:

- (1) Primer-less,
- (2) Low modulus,
- (3) Does not contain solvents or diluents that can cause shrinkage or expansion during curing,
- (4) Smooth and uniform in appearance with a consistency that allows application with air pressure guns or hand caulking applicators,

- (5) Capable of withstanding repeated joint movement from -50 percent to 100 percent without losing adhesion to the concrete and without cohesion failure, and
- (6) Listed on the Approved Products List.

3722.3 SAMPLING AND TESTING

Provide samples at rates and sizes meeting the requirements of the Schedule of Materials Control or as required by the contract.

3723 HOT-POURED, ELASTIC TYPE JOINT AND CRACK SEALER

3723.1 SCOPE

Provide hot-poured elastic type joint and crack sealer to seal joints and cracks in concrete and bituminous pavements, bridges, and other structures.

3723.2 REQUIREMENTS

Provide a sealant material meeting the following requirements:

- (1) Listed on the Approved/Qualified Products List;
- (2) Composed of a combination of polymeric materials, fully reacted chemically to form a homogeneous compound;
- (3) When melted, ensure the sealant does not separate or settle and ensure the sealant does not contain a dispersed or settling component, and
- (4) Maintains a uniform consistency to seal joints and cracks without large air holes or discontinuities.

A.....Physical Requirements

Provide sealant meeting the requirements of ASTM D 6690, Type II and the following modifications:

Table 3723-1 ASTM D 6690, Type II Modifications	
Test	Requirement
Cone penetration at 77 °F [25 °C], 150 g, 5 s	60 – 90 dmm
Bond at -20 °F [-29 °C], 3 cycles, 100% extension	No adhesion or cohesion bond failure after 3 cycles
Mandrel bend test at -29 °F [-34 °C], 1 in [25 mm] mandrel	No cracking
Resilience at 77 °F [25 °C]	≥ 40%

B.....Packaging and Marking

Package and ship the sealant material in boxes no greater than 50 lb [23 kg]. Mark the containers with the following information:

- (1) Material name,
- (2) Manufacturer name,
- (3) Brand name,
- (4) Weight,
- (5) Batch number, and
- (6) Maximum heating temperature, as recommended by the manufacturer.

3723.3 SAMPLING AND TESTING

A.....Sampling

Provide samples in rates and sizes meeting the requirements of the Schedule of Materials Control, or as required by the contract.

The Materials Engineer will perform tests on samples taken from the product proposed for use. Submit to the Engineer a manufacturer's Certificate of Compliance with each sealant batch.

BMethods of Test

B.1Bond Test

Perform tests meeting the requirements of ASTM D 5329, except perform the bond test using sawed cement mortar blocks or asphalt HMA blocks (consistent with the pavement type) prepared using the methods found in the Laboratory Manual.

B.2Mandrel Bend Test ASTM D 522, Method B

The Materials Engineer will perform the Mandrel Bend Test at -29 °F [-34 °C] using a 1 in [25 mm] mandrel, bending the specimen 180° over 5 s. The Materials Engineer will prepare test specimens meeting the requirements of ASTM D 6690, Type II, Flow Test, and condition the specimens at -29 °F [-34 °C] for at least 4 h.

3725 HOT-POURED, EXTRA LOW MODULUS, ELASTIC TYPE JOINT AND CRACK SEALER

3725.1 SCOPE

Provide hot-poured, extra low modulus, elastic type joint and crack sealer to seal joints in concrete pavement, bridges, other structures and rout and seal applications on bituminous pavements.

3725.2 REQUIREMENTS

Provide a sealant material meeting the following requirements:

- (1) Listed on the Mn/DOT Approved Products List,
- (2) Composed of a combination of polymeric materials, fully reacted chemically to form a homogeneous compound,
- (3) When melted, ensure the sealant does not separate or settle, and
- (4) Maintains a uniform consistency to seal joints and cracks without inclusion of large air holes or discontinuities.

APhysical Requirements

Provide sealant meeting the requirements of ASTM D 6690 Type IV with the following modifications in Table 3725-1.

Table 3725-1 ASTM D 6690 Type IV Modifications	
Test	Requirement
Cone Penetration at 77° F [25° C], ASTM D 5329	100 – 150 dmm
Cone Penetration at 0° F [-18° C], ASTM D 5329 modified	≥ 25 dmm
Resilience, ASTM D 5329	30% – 60%
NOTE: Ensure the material meets the requirements of Table 3725-1 after heating for 6 h with constant mixing in a laboratory melter at the manufacturer's maximum heating temperature.	

BPackaging and Marking

Package and ship the sealant material in boxes weighing no greater than 50 lb [23 kg]. Mark the boxes with the following information:

- (1) Material name,
- (2) Manufacturer name,
- (3) Brand name,
- (4) Weight,

(5) Batch number, and

- (6) Maximum heating temperature recommended by the manufacturer.

3725.3 SAMPLING AND TESTING

Provide samples at rates and sizes meeting the requirements of the Schedule of Materials Control or as required by the contract.

The Materials Engineer will perform tests on samples taken from the product proposed for use. Submit to the Engineer a manufacturer's Certificate of Compliance with each sealant batch.

Perform tests meeting the requirements of ASTM D 5329, except perform the bond test using sawed cement mortar blocks or asphalt HMA blocks [consistent with the pavement type] prepared using the methods found in the Lab Manual.

3726 PREFORMED GASKET SEALS FOR CONCRETE PIPE

3726.1 SCOPE

Provide preformed gasket seals to construct watertight joints for concrete pipe.

3726.2 REQUIREMENTS

Provide preformed gasket type seals to construct flexible, watertight joints in concrete pipe meeting the requirements of AASHTO M 315 and as shown in the plans for the specific joint design of the pipe.

3726.3 SAMPLING AND TESTING

Sample and test in accordance with the Schedule of Materials Control.

3728 BITUMINOUS MASTIC JOINT SEALER FOR PIPE

3728.1 SCOPE

Provide cold applied, mineral filled, joint sealing compound for joints of bell and spigot or tongue and groove, concrete or clay culvert, sewer, or drain pipe.

3728.2 REQUIREMENTS

Provide a bituminous mastic joint sealer consisting of refined petroleum asphalt meeting the requirements of ASTM D 4586, except for the following modifications:

Table 3728-1 ASTM D 4586 Modifications	
Test	Requirement
Grease cone penetration (unworked) 150 g, 77 °F [25 °C], 5 s, ASTM D 217	175 dmm – 300 dmm
Density	≥ 8.75 lb per gal [1.0 kg per L]
Non-volatile content	≥ 65%
Ash content, by ignition	25% – 45%
Cure Evaluation at 77 °F [25 °C]	Tough, plastic coating, free of blisters

Do not use coal tar products.

Provide material exhibiting 100 percent adhesion and cohesion when applied to metal, concrete, or vitrified clay surfaces.

3728.3 SAMPLING AND TESTING

Submit to the Engineer a manufacturer's Certificate of Compliance.

Apply the bituminous mastic joint sealer in a layer $\frac{1}{16}$ in to $\frac{1}{8}$ in [2 mm to 3 mm] thick on a tinned metal panel. Cure the joint sealer at 77 °F [25 °C] for 24 h. An acceptable bituminous mastic joint sealer will set to a tough, plastic coating, free of blisters.

3731 CAULKING COMPOUND

3731.1 SCOPE

Provide caulking compound meeting the requirements of Federal Specification A-A-272, in the type required by the contract.

3731.2 REQUIREMENTS

Apply the caulking compound in accordance with the manufacturer's recommendations.

Unless the contract requires otherwise, use near white, light gray, or buff colored caulking compound.

3731.3 SAMPLING AND TESTING

Sample and test in accordance with the Schedule of Materials Control.

3733 GEOTEXTILES

3733.1 SCOPE

Provide geotextiles (permeable fabrics) for the typical uses classified as follows:

- (1) Type 1 for wrapping subsurface drain pipe, joints of concrete pipe culvert, or other drainage applications;
- (2) Type 2. The Department no longer uses this classification. If the contract specifies Type 2, use Type 3 property requirements;
- (3) Type 3 for use under Class I and Class II random riprap, gabions, and revet mattresses;
- (4) Type 4 for use under Class III and Class IV random riprap and hand-placed riprap on slopes no steeper than 3:1, horizontal to vertical;
- (5) Type 5 for separating materials for stabilization;
- (6) Type 6 for earth reinforcement;
- (7) Type 7 for use under Class III and Class IV random riprap on slopes steeper than 3:1, horizontal to vertical, and under Class V random riprap.

3733.2 REQUIREMENTS

A..... General

Provide geotextiles consisting of woven, nonwoven, or knit fabric of polymeric filaments or yarns, such as polypropylene, polyethylene, polyester, or polyamide, that form a stable network. Knit fabric shall only be used as perforated pipe wrap. Provide geotextile resistant to biological and chemical environments normally found in soils, and that is free of chemical treatment or coating that may significantly reduce porosity or permeability.

Provide geotextile that is uniform in texture, thickness, and appearance, and is free of defects, flaws, or tears that may alter the strength or filtering properties. Repair geotextile as approved by the Engineer.

Deliver rolls of geotextile or geotextile-wrapped perforated pipe with an opaque plastic covering to protect the material from ultraviolet rays or contamination with mud, dirt, dust, or debris. Provide rolled geotextile labeled on the outside wrap and inside the core in accordance with ASTM D 4873 and as follows:

- (1) Manufacturer,
- (2) Product name, and
- (3) Roll number.

Ensure unprotected geotextile is not exposed to sun for more than seven days. Replace contaminated geotextile or geotextile exposed to the sun for more than seven days, if directed by the Engineer.

Provide geotextile meeting the requirements of Table 3733-1 for the type required by the contract.

If using Type 5 or Type 6 geotextile, produce seams meeting the requirements of Table 3733-1, row B3, "Seam Breaking Strength Minimum."

B Physical Properties

Table 3733-1 Geotextile Properties								
Geotextile Property	Test Method (ASTM)	Type (a)						
	Units	1		3	4	5	6	7 (c)
		Fabric	Knit sock (b)					
B1 Grab Tensile Strength minimum, each principal direction	D4632 lb [kN]	100 [0.45]	—	100 [0.45]	200 [0.90]	200 [0.90]	(d)	300 [1.3]
B2 Elongation minimum, each principal direction	D4632 percent	—	—	50	50	—	(d)	50
B3 Seam Breaking Strength minimum (e)	D4632 lb [kN]	90 [0.40]	—	90 [0.40]	180 [0.80]	180 [0.80]	(d)	270 [1.2]
B4 Apparent Opening Size (AOS) maximum (f)	D4751 U.S. Std. sieve size [mm]	40 [0.425]	40 [0.425] as applied	50 [0.30]	50 [0.30]	30 [0.60]	20 [0.85]	50 [0.30]
B5 Permittivity minimum (g)	D4491 falling head sec ⁻¹	0.7	2.75 relaxed	0.5	0.5	0.05	0.05	0.5
B6 Puncture strength minimum	D6241 lb [N]	—	180 [800]	—	—	—	—	—
B7 Wide Width Strip Tensile Strength minimum each principal direction	D4595 lb/ft [kN/m]	—	—	—	—	—	(d)	—

(a) Minimum Average Roll Values (MARV) based on average of at least three tests per swatch.
 (b) Provide socks made of knit polymeric materials and meeting the requirements of ASTM D6707-06, for Type H: fabric. Ensure the sock exhibits minimum snag or run potential, is factory-applied to maintain uniform installed mass, and conforms to the outside diameter of the tubing with a snug fit.
 (c) Needle-punched nonwoven. Do not use thermally bonded (heat-set) fabric.
 (d) Requirements are site-specific and will be as specified in the contract. The property values for B1 and B3 may not be less than shown for Type 5. If the contract does not specify either B1 or B7, use a default value of 300 lb [1.3 kN] for B1. If the contract does not specify seam strength, use a default value of 270 lb [1.2 kN] for B3.
 (e) Adhere to this requirement if the contract requires or allows seams. Strength specifications apply to factory and field seams. Use thread for sewing that has strength of at least 25 lb [110 N]. Sew seams with a Federal Type 401 stitch using a two-spool sewing machine, and install seams facing upward. For seaming with adhesives, see the Approved/Qualified Products List available at the Department's website.
 (f) For U.S. sieve sizes, the AOS Number must be equal to or greater than the number specified.
 (g) Permittivity: $P = K/L$, where K = fabric permeability and L = fabric thickness.

3733.3 SAMPLING AND TESTING

A.....Certificate of Compliance

Ensure the supplier submits to the Engineer a Certificate of Compliance and a document stating the manufacturer's MARV with each shipment of geotextile. MARV are two standard deviations below the mean value of all rolls tested. Provide a copy of the Certificate of Compliance and MARV with each geotextile sample sent to the Materials Laboratory for testing.

B.....Sampling and Testing

The Department's inspection and test results will determine acceptance of the geotextile, in accordance with 1603.4, "Acceptance." In the presence of the Engineer, randomly select samples in the field at the rates and sample sizes shown in the Schedule of Materials Control. Cut samples across the full width of the roll. Do not sample the first full turn (outside layer) of the roll. Provide seam samples in addition to the regular sample. Use the same machine, or an equal machine to the one on the project, to produce seam samples.

CONCRETE CURING MATERIALS

3751 BURLAP CURING BLANKETS

3751.1 SCOPE

Provide burlap cloth for use as a curing cover on portland cement concrete.

3751.2 REQUIREMENTS

Provide burlap cloth meeting the requirements of AASHTO M 182, Class 3 for use as a curing cover on portland cement concrete.

3751.3 SAMPLING AND TESTING

Provide samples for testing meeting the requirements of the Schedule of Materials Control.

3753 TYPE 1-D MEMBRANE CURING COMPOUND

3753.1 SCOPE

Provide clear or translucent liquid membrane forming curing compounds with a Type 1-D fugitive dye for spray application on portland cement colored or stamped concrete surfaces, where a finished white surface would mask the decorative finished concrete surface when exposed to the air.

3753.2 REQUIREMENTS

A.....General

Provide membrane curing compound meeting the following requirements:

- (1) All membrane-curing compounds pre-approved by the Department before use. The most current approved lots and batches with product expiration dates are available on the Approved/Qualified Products List,
- (2) Meets the requirements of the Department's Curing Compound Manufacturer Approval Program, as listed in the Approved/Qualified Products List, including pre-testing of materials by the manufacturer,
- (3) Meets the requirements of ASTM C 309, Type 1-D Curing Compound, and
- (4) The Engineer will not allow the use of curing compound that is over 1 year from the manufacture date.

The Contractor may use Type 1-D curing compound in other concrete applications as approved by the Engineer or as shown on the special provisions. Use of any other Type 1 curing compound is at the discretion of the Engineer, in conjunction with the Concrete Engineer.

3753.3 SAMPLING AND TESTING

Provide samples for testing meeting the requirements of the Schedule of Materials Control.

Test the material at an application rate of 200 sq. ft per gal [5 sq. m per L].

3754 POLY-ALPHA METHYLSTYRENE (AMS) MEMBRANE CURING COMPOUND

3754.1 SCOPE

Provide poly-alpha methylstyrene liquid membrane curing compounds for spray application on portland cement concrete surfaces exposed to the air.

3754.2 REQUIREMENTS

Provide membrane-curing compound meeting the following requirements:

- (1) All membrane-curing compounds pre-approved by the Department before use. The most current approved lots and batches with product expiration dates are available from the Approved/Qualified Products List.
- (2) Meets the requirements of the Department's Curing Compound Manufacturer Approval Program, including pre-testing of all materials by the manufacturer.
- (3) Meets the requirements of ASTM C 309 for the type required by the contract.
- (4) The Engineer will not allow the use of curing compound that is over 1 year from the manufacture date.
- (5) White pigmented Type 2, Class B.
- (6) Resin is 100 percent poly-alpha methylstyrene and formulated to maintain the specified properties of Table 3754-1.

Table 3754-1 Requirements for 3754 AMS Curing Compound	
Properties	Range
Total solids, % by weight of compound	≥ 42
% reflectance in 72 h (ASTM E 1347)	≥ 65
Loss of Water, kg/sq. m in 24 h (ASTM C 156)	≤ 0.15
Loss of Water, kg/sq. m in 72 h (ASTM C 156)	≤ 0.40
Settling Test, ml/100 ml in 72 h*	≤ 2
V.O.C. Content, g/L	≤ 350
Infrared Spectrum, vehicle	100% α methylstyrene
* Test in accordance with the method on file at the Materials Laboratory.	
Match the infrared scan for the dried vehicle from the curing compound to the infrared scan on file at the Materials Laboratory.	

3754.3 SAMPLING AND TESTING

Provide samples for testing meeting the requirements of the Schedule of Materials Control.

Test the material at an application rate of 200 sq. ft per gal [5 sq. m per L].

3755 LINSEED OIL MEMBRANE CURING COMPOUND

3755.1 SCOPE

Provide extreme service white pigmented, heavy bodied linseed oil emulsion for application as a membrane cure and sealer.

3755.2 REQUIREMENTS

Provide membrane curing compounds meeting the following requirements:

- (1) All membrane-curing compound pre-approved by the Department before use. The most current approved lots and batches with product expiration dates are available on the Approved/Qualified Products List.
- (2) Meets the requirements of the Department's Curing Compound Manufacturer Approval Program, including pre-testing of materials by the manufacturer.
- (3) Composed of a blend of boiled linseed oil and high viscosity, heavy bodied linseed oil emulsified in a water solution meeting the requirements of ASTM C 309, Type 2, except the Department will waive the drying time.
- (4) The Engineer will not allow the use of curing compound that is over 1 year from the manufacture date.
- (5) Sprayable at temperatures of at least 40 °F [4 °C].
- (6) Formulated to maintain the specified properties of Table 3755-1.

Table 3755-1 Chemical Requirements of Linseed Oil Membrane Curing Compound (volumes exclusive of added pigment)	
Material Requirements	Percent by Weight
Oil phase (50% ± 4% by volume):	
Boiled linseed oil	80
Z-8 viscosity linseed oil	20
Water phase (50% ± 4% by volume)	100

3755.3 SAMPLING AND TESTING

Provide samples for testing meeting the requirements of the Schedule of Materials Control.

Test membrane curing compound at an application rate of 200 sq. ft per gal [5 sq. m per L].

3756 PLASTIC CURING BLANKETS

3756.1 SCOPE

Provide white polyethylene sheeting for use as a curing cover on portland cement concrete.

3756.2 REQUIREMENTS

Provide white polyethylene sheeting meeting the requirements of ASTM C 171, "White Opaque Polyethylene Film."

3756.3 SAMPLING AND TESTING

Provide samples for testing meeting the requirements of the Schedule of Materials Control.

3757 MEMBRANE WATERPROOFING SYSTEM

3757.1 SCOPE

Provide a membrane waterproofing system to be used for waterproofing below-grade joints in concrete structures, tunnels, and other below grade applications on concrete structures.

3757.2 REQUIREMENTS

Provide a membrane waterproofing system meeting the following requirements:

- (1) Listed on the Approved/Qualified Products List, and
- (2) Consists of a primer, a rubberized asphalt membrane on a cross-laminated polyethylene carrier film, an pointing mastic, and a protection course.

A.....Primer

Provide a solvent-based primer meeting the requirements of Federal and Minnesota Pollution Control Agency VOC regulations and specially formulated for use with the waterproofing system being used.

B.....Membrane

Provide waterproofing system with a membrane meeting the requirements of Table 3757-1:

Table 3757-1 Waterproofing Membrane Requirements		
Property	Specification	Test Method
Thickness	≥ 56 mil [1.42 mm]	ASTM D 3767, Method A
Tensile strength	≥ 250 psi [1.7 MPa]	ASTM D 412, Die C
Elongation	≥ 300%	ASTM D 412, Die C
Composition	Rubber asphalt	Infrared scan

C.....Carrier Film

Provide membrane waterproofing system with carrier film meeting the requirements of Table 3757-2:

Table 3757-2 Waterproofing Carrier Film Requirements		
Property	Specification	Test Method
Thickness	≥ 4 mil [0.1 mm]	ASTM D 3767, Method A
Composition	Polyethylene	Infrared scan

D.....Composite Membrane

Provide membrane waterproofing system with a composite membrane meeting the requirements of Table 3757-3:

Table 3757-3 Waterproofing Composite Membrane Requirements		
Property	Specification	Test Method
Pliability, 180° bend, 1 in [25 mm] mandrel at -25 °F [-32 °C]	Unaffected	ASTM D 146
Permeance	< 0.05 Perms	ASTM E 96, Method B
Peel adhesion	≥ 5 lb/in [kg/mm]	ASTM D 903 Modified*
Water absorption	-0.1%, 72 h	ASTM D 1970
* 90 percent peel after 7 days at 70 °F [21 °C], plus 7 days at 120 °F [49 °C], plus 7 days at 70 °F [21 °C] (dry) (wet). The 180° peel strength is run at a rate of 12 in [300 mm] per minute.		

3757.3 SAMPLING AND TESTING

Provide samples in rates and sizes meeting the requirements of the Schedule of Materials Control, or as required by the contract.

The Materials Engineer, may perform tests on samples taken from the product proposed for use or on samples submitted and certified by the manufacturer as representative of the membrane waterproofing system to be supplied.

3760 INSULATION BOARD (POLYSTYRENE)

3760.1 SCOPE

Provide extruded polystyrene insulation board for use on highway insulation applications.

3760.2 REQUIREMENTS

Provide extruded polystyrene insulation board used for highway insulation applications meeting the requirements of AASHTO M 230, except the Department will not apply the requirement for flammability. The contract will identify the selected type of insulation board and the insulation board strength as listed in AASHTO M 230.

3760.3 SAMPLING AND TESTING

Provide samples meeting the requirements of the Schedule of Materials Control.

MISCELLANEOUS MATERIALS

3902 FORM COATING MATERIAL

3902.1 SCOPE

Provide form coating material that will prevent bonding between a form, dowel, or other object and concrete.

3902.2 REQUIREMENTS

Provide form coating material listed on the Approved/Qualified Products List and meeting the following requirements:

- (1) Made of a chemical release agent that does not contain ordinary lubrication oil, conventional form oil, fuel oil, or kerosene, and has a flash point of at least 149 °F [65 °C] when tested in accordance with ASTM D 92;
- (2) Prevents bonding to concrete;
- (3) Does not penetrate, stain, or leave a residual film on the concrete surface; and
- (4) Does not attract dirt or other deleterious matter.

Apply the form coating material at a rate recommended by the manufacturer to provide a smooth surface free of dusting action caused by reactions of the chemical release agent.

As a substitute for a form coating material listed on the Approved/Qualified Products List, the Contractor may provide dowel bars, baskets, and reinforcement bars coated with a factory applied, Department-approved petroleum, paraffin based lubricant.

3902.3 SAMPLING AND TESTING — (BLANK)

3906 WATER FOR CONCRETE AND MORTAR

3906.1 SCOPE

Provide water for use in mixing and curing portland cement concrete and mortar.

3906.2 REQUIREMENTS

Provide water approved by the Engineer and meeting the following requirements for mortar or concrete:

- (1) Not salty or brackish
- (2) Clean, and
- (3) Free of injurious quantities of deleterious substances such as oil, acid, alkali, and organic matter.

The Engineer will allow potable water without testing.

The Engineer may conduct testing to determine allowable use of a Contractor proposed water source. The Engineer will reject the water, if any of the test results in accordance with AASHTO T 26 show the following:

- (1) Unsoundness
- (2) Change in time of setting greater than 1 h earlier or greater than 1½ h later, or
- (3) A reduction of greater than 10 percent in the 7-day mortar strength.

Before using clarified wash water for concrete and mortar, submit a request to the Engineer for review and approval by the Concrete Engineer.

3906.3 SAMPLING AND TESTING

Provide representative samples of water in clean containers to the Engineer for testing as required by the Schedule of Materials Control.

3910 ROCK SALT

3910.1 SCOPE

Provide rock salt for use as a deicer for road construction and maintenance purposes.

3910.2 REQUIREMENTS

Provide rock salt meeting the following requirements at the time of delivery:

- (1) ASTM D 632 for Type 1, Grade 1 material;
- (2) Free of lumps, aggregations, and foreign matter; and
- (3) With no greater than 1.5 percent moisture content.

3910.3 SAMPLING AND TESTING

The Engineer may sample and inspect the rock salt at the supplier's unloading and storage facilities or at the point of delivery.

The Engineer, in conjunction with the Materials Engineer, will perform the following:

- (1) Sampling meeting the requirements of ASTM D 632, as modified by the Laboratory Manual;
- (2) Moisture testing in accordance with the Laboratory Manual;
- (3) Sieve analysis meeting the requirements of ASTM C 136 for Sieve Analysis of Fine and Coarse Aggregate, as modified by the Laboratory Manual; and
- (4) Chemical analysis for determination of sodium chloride content meeting the requirements of the Rapid Test Method for Sodium Chloride by Silver Nitrate Potentiometric Titration or the Reference Method for Chemical Analysis of Sodium Chloride as modified by the Laboratory Manual.

3911 CALCIUM CHLORIDE

3911.1 SCOPE

Provide liquid and solid calcium chloride for use in dust control, accelerating the hardening of concrete, and other purposes.

3911.2 REQUIREMENTS

Provide liquid or solid calcium meeting the requirements of AASHTO M 144 for the type and grade required by the contract. Unless the contract requires otherwise, provide liquid calcium chloride with at least 38 percent anhydrous CaCl_2 by weight. Provide liquid calcium chloride that is clear and free of solid matter.

3911.3 SAMPLING AND TESTING

Provide samples at rates and sizes meeting the requirements of the Schedule of Materials Control or as required by the contract.

Perform sampling in accordance with ASTM D 345.

The Materials Engineer will perform tests meeting the requirements of ASTM D 345.

3912 MAGNESIUM CHLORIDE SOLUTION

3912.1 SCOPE

Provide magnesium chloride solution for dust control or other purposes.

3912.2 REQUIREMENTS

Provide magnesium chloride solution meeting the following characteristics and requirements:

- (1) Water clear,
- (2) Free of deleterious substances,
- (3) Consists primarily of magnesium chloride,
- (4) Anhydrous magnesium chloride content of at least 28 percent by mass,
- (5) SO₄ sulfate content no greater than 3.5 percent by mass, and
- (6) Alkali chlorides content no greater than 5 percent by mass.

3912.3 SAMPLING AND TESTING

A..... Sampling

Provide samples at rates and sizes meeting the requirements of the Schedule of Materials Control or as required by the contract.

B..... Testing

The Materials Engineer will perform testing meeting the following requirements:

B.1..... Magnesium chloride, MgCl₂ Laboratory Manual

B.2..... Sulfate, SO₄..... Laboratory Manual

B.3..... Alkali chlorides, as NaCl..... ASTM E 449