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pavement markings are to be applied by State forces, the Contractor's responsibility ends after completion of the fog seal and placement of temporary pavement markings.

I. Application of Bituminous Material for Fog Sealing

Fog seal completed seal coated areas, after sweeping and before placement of permanent pavement markings. Construct the fog seal as specified in Mn/DOT 2355, as modified as follows: Construct a 30 meter [100 foot] test strip. Review the application of diluted (1:1) bituminous material and adjust the application rate as needed. Apply between 0.3 to 0.8 liters per square meter diluted [0.07 to 0.18 gallons per square yard, diluted]. Apply the fog seal to minimize the amount of overspray. Do not allow traffic on the fog seal until it has cured.

J. Progress of Work

The seal coat will usually cure within 24 hours under dry conditions and temperatures above 15.5 °C [60 °F]. Allow the seal coat to cure a minimum of one day before fogging. The fog seal can be applied after the seal coat is cured. The fog seal will usually cure within 2 hours under dry conditions and temperatures above 15.5 °C [60 °F]. Interim pavement markings can be placed after the fog seal cures. The permanent pavement markings shall not be placed for three days after placing the fog seal.

S-142.6 METHOD OF MEASUREMENT

A. Bituminous Material

1. Measure the bituminous material for fog seal by volume, at 15 °C [60 °F], **undiluted**. This material must be diluted (1:1) before application at place of manufacture.
2. Measure the bituminous material for seal coat by volume, at 15 °C [60 °F].

B. Seal Coat

Measure the seal coat by area of pavement surfaced.

S-142.7 BASIS OF PAYMENT

(A) Payment for bituminous material for fog seal: as specified in Mn/DOT 2355.5.

(B) Payment for the accepted quantity of bituminous material for seal coat (including any required additives) at the Contract bid price of measure is compensation in full for all costs of furnishing and applying the material as specified.

(C) Payment for the accepted quantity of seal coat at the Contract bid unit price of measure is compensation in full for all costs of furnishing and applying the material as specified, including cleaning the existing pavement, stationing, purchasing of aggregate, delivery of aggregate, all labor, equipment, and materials necessary for the placement of the seal coat for full lane coverage, sweeping of any loose aggregate after construction and other requirements as specified.

(D) Payment will be made in accordance with the schedule set forth below at the Contract bid price for the specified unit of measure. Such payment, in each instance, is compensation in full for all costs incidental thereto.

<u>Item No.</u>	<u>Item</u>	<u>Unit</u>
2355.502	Bituminous Material for Fog Seal.....	Liter [Gallon]
2356.505	Bituminous Material for Seal Coat	Liter [Gallon]
2356.604	Bituminous Seal Coat.....	Square meter [Square yard]

S-143 (2356) SEAL COAT - MACRO-SURFACING

Use on very high volume roadways like freeways

SP2005-137

Mn/DOT 2356 is hereby deleted and replaced with the following:

S-143.1 DESCRIPTION

Macro-surfacing is a high macro-texture surface treatment applied in a continuous operation. Macro-surfacing is suitable for high-speed, high-volume applications and is designed for fast return to traffic. Apply a climate-specific polymer modified asphalt emulsion (macro-surfacing emulsion), followed immediately by the application of a single layer of aggregate. Fog seal all macro-surfacing, after sweeping and before placement of permanent pavement markings.

S-143.2 MATERIALS

A. Bituminous Material

Provide bituminous material for macro-surfacing as specified in Mn/DOT 3151.2E, as modified, by the following:

Modify the base asphalt with the polymer, prior to emulsification. The emulsion, upon standing undisturbed for a period of 24 hours, shall show no white milky colored substance on its surface, and shall be a homogeneous brown color throughout. The emulsion shall meet the requirements in Table 1.

Table 1. Macro-surfacing Emulsion

Tests on Emulsion	Method	Min	Max
Sweep Test	TM101		15
Sieve test ¹ , %	AASHTO T-59		0.5
Viscosity ^{1,2} , Saybolt Furol @ 50 °C [122 °F], sec.	AASHTO T-59	25 ²	600 ²
Residue from Distillation at 204.4 °C [400 °F], %	AASHTO T-59	65	
Oil distillate by volume of emulsion, %	AASHTO T-59		2
Tests on Base Asphalt			
Penetration @ 25 °C [77 °F]	ASTM D 5-97	60 - 120	
Elastic Recovery, 10 °C [50 °F], %	AASHTO T-301	60	
¹ Viscosity or sieve requirements may be waived if the material has been successfully applied in the field.			
² Viscosity samples shall be tested at the producing plant prior to shipping to the job site. Range set to accommodate regional and climactic requirements.			

Provide a CSS-1 or CSS-1h bituminous material for fog seal as specified in Mn/DOT 3151.2E

B. Aggregate.

Provide a Class A or Class C aggregate, as specified in Mn/DOT 3137.2B. Mechanically crush the aggregates to meet the requirements in Table 2.

Table 2. Aggregate Properties

Aggregate Tests	Method	Min	Max
Fractured Faces Single face, %	ASTM D5821	98	
Two or more faces, %		95	
Flakiness Index, %	FLH T 508		17
Micro-Deval	AASHTO TP 58		17
Deleterious materials, %	TM102		0.5
Absorption, %	ASTM C127		2
Sieve Analysis	(AASHTO T 27)	% Passing	
9.5 mm [3/8 inch]		100	
4.75 mm [# 4]		0-12	
75 µm [# 200]		0.0-1.0	

Schedule of Price reduction for Seal Coat - Macro-Surfacing.

Failing gradations will result in a price reduction. The Contract price for Seal Coat - Macro-Surfacing will be reduced 2 percent, for each 1 percent passing outside of the requirements for the 9.5 mm [3/8 inch] and 4.75 mm [# 4] sieve. The 75 µm [# 200] sieve will have 2 percent price reduction for each 0.1 percent outside of the specification.

S-143.3 **MIX DESIGN**

The quantities on the Plans for macro-surfacing emulsion and aggregate are for estimating purposes only. Design the Macro-surfacing using Mn/DOT's seal coat design method. Qualified personnel experienced in asphalt surface treatment design will prepare the design.

Base the design on the traffic volume(s) and pavement condition(s). Determine the final application rate for the asphalt binder and cover aggregate after the source of the material is known and field adjustments are made. Provide the following design information to the Project Engineer:

- (1) All test results required in Tables 1 and 2.
- (2) Penetration results of emulsion.
- (3) Bulk specific gravity of the aggregate.
- (4) Loose unit mass [**weight**] of the aggregate.
- (5) Asphalt type and rate of application.
- (6) Aggregate rate of application.

S-143.4 **EQUIPMENT**

A. Macro-Surfacing Application Vehicle

Apply a uniform application of macro-surfacing emulsion and cover aggregate without the application vehicle driving on the newly applied surface. Provide integrated dual spray bars and aggregate spread hoppers whose width can be varied independently during operation. Continuously apply the macro-surfacing emulsion and aggregate. Apply the aggregate so that no more than a length of 1219 mm [**48 inches**] of emulsion application is on the road surface without cover aggregate. All systems for the application of materials shall be computer controlled.

B. Spread Hopper

Use a variable width hopper system including drive augers and spread rolls. Synchronized the hopper width and the spray bar width, in continuously variable 102 mm [**4 inch**] increments. Use a continuous conveyor feed to the hopper system. Cover the spread hopper with a full-width screen to reject all oversized materials and foreign objects. Calibrate the aggregate spreader in accordance with ASTM D5624-95. The allowable deviation in the amount of aggregate spread both transverse and longitudinal direction is $\pm 0.5 \text{ kg/m}^2$ [**±1.0 pound per square yard**].

C. Control Systems.

Monitor the speed of the Macro-Surfacing Application Vehicle using the aggregate Application Rate Computer. Vary the gate opening in order to maintain the set application rate, in kg per square meters [**pounds per square yard**], of the aggregate, regardless of forward speed. Adjust either aggregate or emulsion application rate during vehicle operation using the Application Rate Computer. Set the Macro-Surfacing Application Vehicle's forward speed for consistent operation using the computer. The binder and aggregate Application Rate Computer(s) shall vary the output of macro-surfacing emulsion pumps and/or aggregate application rate to maintain the desired macro-surfacing emulsion application rate, regardless of variations in ground speed, changes in application width, and operator inputs of desired application rate(s). Record: liters [**gallons**] of emulsion sprayed, length of roadway surfaced, and area of roadway surfaced, using the computer(s).

D. Macro-Surfacing Emulsion Application System.

Apply the bituminous material with a distributor system as specified in Mn/DOT 2321.3C1, and as modified below.

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Provide an insulated macro-surfacing emulsion tank on the Macro-surfacing Application Vehicle. Access for cleaning and a functional capacity gage are required. Provide for the transfer of additional macro-surfacing emulsion into the tank during continuous operation.

Provide pumps and plumbing systems to feed the spray bars. Supply removable strainers to remove foreign material from the macro-surfacing emulsion before it enters the spray bars.

Allow for positive circulation from one end of the spray bar to the other end. Space nozzles no greater than 102 mm [**4 inch**] on centers on the spray bars. Provide an individual valve for each spray nozzle, so the spray width can be adjusted synchronously with the aggregate hopper width during operation. Synchronize the spray bar operating width with the aggregate hopper width, with a width continuously variable in not greater than 102 mm [**4 inch**] increments.

Spray the macro-surfacing emulsion by a metered mechanical pressure spray bar at a temperature above 42 °C [**108 °F**], or as recommended by the Macro-surfacing Emulsion supplier. Accurately and continuously monitor the rate of spray. Provide a uniform application across the entire width of the pavement.

Measure and record the total emulsion applied, with an accuracy of $\pm 10\%$. Maintain a daily log recording the total area covered and the total volume of emulsion applied. Compare this data to the calibrated application rates.

E. Support vehicles.

Provide for continuous feeding and operation of the Macro-surfacing Application Vehicle. Simultaneously feed both aggregate and macro-surfacing emulsion to the Macro-surfacing Application Vehicle. Supply the materials while the Macro-surfacing Application Vehicle is moving forward.

F. Rollers.

Mn/DOT 2321.3C2 is deleted and replaced with the following. Use self-propelled pneumatic-tired rollers that weigh between 11.3 t [**12.5 tons**] and 22.7 t [**25 tons**]. Ensure full width coverage of the macro-surface in a single paving pass. Use smooth pneumatic tires. Provide a minimum effective rolling width of approximately 1.7 m [**5.7 feet**].

Ground contact pressure will be 552 kPa [**80 psi**] or more. Operate at load and tire pressure within the range of the manufacturer's charts showing the contact areas and contact pressures for the full range of tire inflation pressures and for the full range of loadings for the particular tires furnished. The rollers shall be within plus or minus 34.5 kPa [**5 psi**] of each other.

The power unit shall move the operating rollers at variable uniform speeds up to a maximum of 8 km per hour [**5 miles per hour**]. Automatic tire cleaning scrapers will remove any aggregate that adheres to the roller tires during operation. The cleaning system shall be operational during construction.

G. Aggregate removal equipment.

Rotary brooms of various types are normally used for excess aggregate removal, although regenerative vacuums, pick-up brooms, and other types may be used as well.

Controlled uniform sweeping pressure is required, across the width of the broom. Equipment tires shall have road tread. Tractor tires are not permitted. The equipment shall have variable down pressure, (a "float" setting), variable angle of approach, and independently controllable variable rotational speed. Provide straight broom bristles, a minimum of 127 mm [**5 inches**] in length, and uniform length across the width of the broom. Keep the axis of the broom parallel to the road surface at all times. Operate the broom to contact the pavement uniformly across the entire width of the broom

H. Macro-surfacing Emulsion Storing and Handling Equipment.

Provide clean equipment, in good operating condition, to store or handle macro-surfacing emulsion. Do not contaminate the macro-surfacing emulsion. Transfer the emulsion directly to the application

equipment from the transport tankers. Storage is not permitted other than in the transport tanker or the feed vehicle tanks. The duration of such storage shall not exceed 48 hours after delivery to the job site. Emulsion not used within 48 hours of initial delivery shall be returned to the producing facility. Provide and maintain a temperature measuring device. Maintain the temperature of the macro-surfacing emulsion at a minimum of 60 °C [140 °F]. No on site heating of macro-surfacing emulsion is allowed. Macro-surfacing emulsion shall not be stored in the application vehicle overnight.

I. Distributor for Bituminous materials for Fog Seal

Provide a distributor meeting the requirements of Mn/DOT 2321.3C1.

S-143.5 CONSTRUCTION

A. Weather Limitations.

Construct seal coat macro-surfacing (including traffic restrictions on the freshly constructed seal coat):

- (1) Not before May 15 nor after August 31; for the part of Minnesota located south of the Northern Spring Road Restriction Zone.
- (2) Not before May 15 nor after August 10, for the part of Minnesota located in the Northern Road Spring Restriction Zone, including roadways making up the southern border of the zone.
- (3) Only during daylight hours. The Engineer must approve other times.
- (4) When the pavement and air temperature are 15 °C [60 °F] and rising.
- (5) When the road surface is dry and clean.

B. Surface Preparation.

Clean all roadway surfaces. Sweep the pavement with a motorized broom to remove all loose material. Clean all depressions not reached by the power broom, using hand brooming. Also, clean the outer edges of the pavement to be sealed including 0.3 m [1 foot] of the shoulder width.

Cover all iron (manholes, gate valve covers, catch basins, etc.) to prevent adherence of the asphalt binder. Suitable covering includes plywood disks, sand, Kraft paper, roofing felt or other approved methods. Remove the protective coverings before opening the road to traffic.

C. Test Section.

Construct a test section for new or unproven systems to demonstrate adequate compliance with this specification prior to any Project work. Demonstrate that the system is capable of final sweeping without damage within one hour after application. Use materials that will be used in the actual Project. The Engineer will locate the test section, which shall be one lane, in width and not to exceed 400 m [1300 feet] in length or an equivalent area. If the application to the test section is unsuccessful, the Contractor shall make the necessary corrections and apply a new test section. All costs are incidental.

Construct a new test strip when the job mix changes or there is field evidence that the system is out of control. The system includes the following:

- Emulsion
- Aggregate type
- Aggregate size

In place of construction of a test strip, submit evidence of a successful construction of a test strip on another State project using the same mix designs. The project must have been constructed the same construction season. The system used for the test strip must be identical to all parts of the proposed system.

D. Material Application

Prior to starting the application, sufficient materials shall be available for continuous application. The aggregate should be visibly moist for proper application. If necessary, spray the material with water to maintain moisture. No free water should be evident in the supply vehicles.

Feed vehicles shall transfer aggregate to the application vehicle without spillage to prevent the presence of loose aggregate on the road surface prior to emulsion application

Paper or other suitable material shall be used to prevent overlapping of transverse joints. Longitudinal joints shall match lane lines.

E. Rolling

Use a minimum of 3 rollers, more may be required depending on the planned application width, speed, and rolling pattern. Roll the entire surface a minimum of one time within 2 minutes of emulsion and aggregate application. Complete additional rolling within 5 minutes of emulsion and aggregate application.

F. Excess Aggregate Removal

Aggregate sweepings shall not be re-applied to the Project. Remove surplus aggregate from the finished surface by brooming. Particular attention should be given to all construction seams. Sweep all areas of the surface a minimum of three times. Keep pace with the application vehicle.

Final removal of all excess aggregate shall be within one (1) hour following the application of materials. Stop the construction process until satisfactory performance is achieved.

G. Release to Traffic

Release the application area to normal traffic after excess aggregate has been removed. Release the road to normal traffic within 2 hours of material application. Stop the construction process until satisfactory performance is achieved.

H. Application of Bituminous Material for Fog Sealing

Fog seal all macro-surfacing, after sweeping and before placement of permanent pavement markings.

Construct the fog seal as specified in Mn/DOT 2355, as modified as follows. Construct a 30 meters [100 foot] test strip. Review the application of diluted emulsion and adjust the application rate as need. Apply between 0.3 to 0.5 liters per square meter [0.07 to 0.12 gallons per square yard].

I. Progress of Work

The seal coat will usually cure within 24 hours under dry conditions and temperatures above 15 °C [60 °F]. The fog seal can be applied when the seal coat is cured. The fog seal will usually cure within 2 hours under dry conditions and temperatures above 15 °C [60 °F]. Pavement markings can be placed after the fog seal cures.

J. Acceptance

Maintain the macro-surface until the Engineer accepts the work. Repair all holes in the surface. Remove and replace failed areas exceeding 2% of the surface area in any 152.4 m [500 feet] lineal section. Cover fat or bleeding surfaces with approved cover material to prevent the asphalt material from sticking to or being picked up by vehicles tires.

S-143.6 QUALITY CONTROL

The Contractor is responsible for quality control (QC) sampling and testing. Prior to production, the Engineer will approve the sampling method used by the Contractor. The Contractor is responsible for the equipment operation and calibration.

A. Aggregate

(1) Testing Rates for Temporary Stockpiles

Test for gradation when the material is placed in hauling vehicles for delivery to a temporary stockpile. The testing rates are a minimum of one per day, or one per 1360t [1500 tons], whichever is greater.

(2) Construction

A minimum of two daily samples of the aggregate will be taken from the Macro-surfacing Application Vehicle and tested for gradation, within two hours. If the average test results vary from the requirements of Table 2, production will stop and a price reduction applied accord to the Schedule of Price Reduction for Macro-surfacing. Identify the cause and document, in detail, the corrective action taken.

B. Emulsion

Provide material certification and quality control test results for each batch of emulsion used on the Project. Include the supplier name, plant location, emulsion grade, and batch number on all reports. The emulsion must meet all requirements in Table 1.

S-143.7 QUALITY ASSURANCE

Mn/DOT is responsible for quality assurance (QA) sampling and testing. Samples cannot be from split samples and must be taken randomly by Mn/DOT.

A. Aggregate

Test a minimum of one sample per day of the cover aggregate for gradation

B. Emulsion

See the Schedule of Materials Control. Samples must be tested within one week of sampling.

S-143.8 METHOD OF MEASUREMENT

A. Bituminous Material

1. Measure the bituminous material for fog seal by volume, **undiluted**, at 15 °C [60 °F].
2. Measure the bituminous material for macro-surfacing by volume, at 15 °C [60 °F].

B. Macro-surfacing

Measure the Macro-surfacing by area of pavement surfaced.

S-143.9 BASIS OF PAYMENT

Payment for bituminous material for fog seal: as specified in Mn/DOT 2355.5.

Payment for the accepted quantity of bituminous material (including any required additives) for macro-surfacing at the Contract bid price of measure shall be compensation in full for all costs of furnishing and applying the material as specified.

Payment for the accepted quantity of Macro-surfacing at the Contract bid price of measure shall be compensation in full for all costs of furnishing and applying the material as specified: including; equipment and labor for removal of the existing pavement markings, cleaning the existing pavement, applying temporary pavement markings, stationing, purchase of aggregate, delivery of aggregate, all labor, equipment, and materials necessary for the placement of the macro-surfacing for full lane coverage, all sweeping of any loose aggregate after construction and other requirements as specified.

<u>Item No.</u>	<u>Item</u>	<u>Unit</u>
2355.502	Bituminous Material for Fog Seal.....	Liter [Gallon]
2356.604	Bituminous Seal Coat – Macro Surfacing.....	Square meter [Square yard]
2356.606	Bituminous Material for Macro Surfacing.....	Liter [Gallon]