

ATTACHMENT
SPECIFICATIONS FOR EPOXY RESIN PAVEMENT MARKINGS
(FREE OF TOXIC HEAVY METALS)

NOTE: Section 10.0 has been revised in the Special Provisions

1.0 DESCRIPTION

The work shall consist of furnishing and installing reflectorized white and yellow two-component, 100 percent solids epoxy pavement markings. Applications are lines, legends, symbols, crosswalks and stop lines placed on properly prepared asphaltic and portland cement concrete pavement surfaces in accordance with the Special Provisions, Plans, this Attachment and as directed by the Engineer. Upon curing, the materials produce pavement markings of specified thickness, width and retroreflectivity that resist wear from high traffic volumes for several years. During darkness and weather permitting, yellow markings shall be readily distinguishable from white markings.

Values stated in the International System of Units SI apply only to projects to be constructed in Metric units of measure. Values stated in inch-pound units (in parenthesis) apply only to projects to be constructed in English units of measure.

2.0 QUALIFICATIONS

- 2.1 Epoxy striping is a technical process requiring specialized equipment, quality controlled materials and well-trained operators to produce functional, long life pavement markings. To minimize application failures, Mn/DOT requires epoxy materials, beads, the pavement marking contractor, and striper to be approved prior to the bidding process.
- 2.1.1 A pavement marking contractor and/or equipment may be qualified as follows:
1. No previous epoxy striping on any construction contract-- contact Mn/DOT to arrange for field demonstration.
 2. Recent epoxy striping experience with other state transportation departments-- contact Mn/DOT and provide experience summary, including names of persons to be contacted.
 3. If striper is new, contact Mn/DOT to arrange for field demonstration.
- 2.1.2 Before any epoxy product is acceptable for bid, it shall be field tested, evaluated, approved and assigned a product identification number by the Mn/DOT Materials Engineering Section. An approved product is placed on the APPROVED PRODUCTS LIST which is shown in Section 2.1.4.
- 2.1.3 No change in product identification, chemical composition as indicated by infrared spectrophotometry and/or chemical analysis, or changes in the application requirements will be allowed. Any such changes shall be submitted for further evaluation.

Mn/DOT EPOXY PAVEMENT MARKING MATERIAL
APPROVED PRODUCTS LIST

2.1.4

Fast Dry (Type I)

<u>Manufacturer</u>	<u>Product</u>	<u>Appr Date</u>
Polycarb Inc.	MARK 55.3	1998
Epoplex	LS 50	1998

<u>Manufacturer</u>	<u>Product</u>	<u>Appr Date</u>
Polycarb Inc.	MARK 55	1991
Epoplex	LS 60	1998

3.0 MATERIAL CLASSIFICATIONS

- 3.1 This specification provides for the classification of epoxy resin pavement marking systems by type.
- 3.1.1 Type I - A fast cure material suitable for line applications and, under ideal conditions, may not require coning.
- 3.1.2 Type II - A slow cure material suitable for all applications of pavement markings under controlled traffic conditions, i.e., coning is required and flagging may be as directed by the Engineer.
- 3.1.2 **Only Slow Dry Type II epoxy material shall be used for epoxy pavement markings except when specified as otherwise in the Special Provisions.**

4.0 EPOXY AND BEAD REQUIREMENTS

- 4.1 Epoxy Resin Material
- 4.1.1 The material shall be composed of epoxy resins and pigments only. No solvents are to be given off to the environment upon application to a pavement surface.
- 4.1.2 The composition shall be within the tolerance permitted for the product tested and approved by Mn/DOT. Type II material shall be completely free of TMPTA (Tri-Methylol Propane Tri-Acrylate) and other multi-functional monomers.
- 4.1.3 All materials shall be free of lead, cadmium, mercury, hexavalent chromium and other toxic heavy metals as defined by the United States Environmental Protection Agency.
- 4.1.4 Color -- The color of the white epoxy shall be a pure flat white, free of tints. The color of the yellow epoxy shall closely match Color Number 33538 of Federal Standard 595 and shall conform to the following CIE Chromaticity limits using illuminant "C":

x | 0.470 | 0.485 | 0.520 | 0.480
y | 0.440 | 0.460 | 0.450 | 0.420

Daylight Directional Reflectance (Y), white, minimum 83
Daylight Directional Reflectance (Y), yellow, minimum 50

Testing will be according to :

Daylight Directional Reflectance ASTM D 2805
Color ASTM D 2805

- 4.1.5 Adhesion Capabilities -- When the adhesion of the material to portland cement concrete (the concrete shall have a minimum of 2,070 kPa (300 psi.) tensile strength) is tested according to American Concrete Institute Committee 403 testing procedure, the failure of the system must take place in the concrete. The concrete shall be 32°C when the material is applied, after which the material shall be allowed to cure for 72 hours at 23±2°C.
- 4.1.6 Abrasion Resistance -- When the abrasion resistance of the material is tested according to ASTM C 501 with a CS-17 wheel under a load of 1000 grams for 1000 cycles, the wear index shall be no greater than 82. (The wear index is the weight in milligrams that is abraded from the sample under the test conditions).
- 4.1.7 Hardness -- The Type D durometer hardness of the material shall be not less than 75 nor more than 90 when tested according to ASTM D2240 after the material has cured for 72 hours at 23±2°C.
- 4.1.8 Tensile Strength -- The tensile strength of the material, when tested according to ASTM D 638, shall not be less than 41,370 kPa (6,000 psi.) after 72 hours cure at 23±2°C.
- 4.1.9 Compressive Strength -- The compressive strength of the material, when tested according to ASTM D 695, shall not be less than 82,700 kPa (12,000 psi.) after 72 hours cure at 23±2°C.
- 4.1.10 Shelf Life -- The individual components shall not require mixing prior to use when stored for a period of 12 months.
- 4.2 Glass Beads
 - 4.2.1 Glass beads shall meet the requirements of AASHTO M247, Type I, and:
 - a. Coatings -- the beads shall be treated according to the manufacturers recommendations and meet the requirements of Section 4.4.2 of M247, and
 - b. Roundness-- the beads shall have a roundness of at least 80%.
 - 4.2.2 For 380 µm (15 mil) applications, glass beads shall be applied at a rate of at least 3.0 kg/L (25 lb./gal.). **A greater bead application rate may be necessary for meeting the performance criteria (minimum levels of retroreflectivity). This will require contractors to consult with all the material manufacturers.**
- 4.3 Time to No-Track -- Type I material shall be in "no-tracking" condition in 15 minutes or less and within 45 minutes for Type II material. The "no-tracking" condition shall be determined on an application of specified thickness to the pavement and covered with glass beads at the rate of at least 3.0 kg/L (25 lb./gal.). The lines for this test shall be applied with striping equipment operated so as to have the material at manufacturer's recommended application temperature. This maximum "no-tracking" time shall not be exceeded when the pavement temperature varies from 10 to 49° C (50 to 120° F) and under all humidity conditions, providing the pavement is dry. The no-tracking time shall be determined by passing over the line with a passenger car or pickup truck at a speed of 40 to 55 kmph (25 to 35 mph) in a simulated passing maneuver. A line showing no visual deposition of the material to the pavement surface when viewed from a distance of 15 m (50 ft.) shall be considered as showing "no-tracking" and conforming to this requirement for time to "no-track."

5.0 APPLICATION EQUIPMENT AND PROCEDURES

5.1 Equipment

- 5.1.1 Equipment furnished shall include an applicator truck of adequate size and power, designed to apply an epoxy resin material and glass beads in a continuous or intermittent line pattern. The equipment shall be capable of placing stripes on the left and right sides. The left carriage shall be capable of placing two lines simultaneously with either line in a solid or intermittent pattern in yellow or white. With change in color usage, an amount of material equal to fifteen 3 m (10 ft.) stripes shall be wasted to eliminate the change of the incorrect color being applied.
- 5.1.2 The applicator truck (striper) and other vehicles in the striping train shall have permanently mounted Type C flashing arrowboards. They shall be visible to oncoming or following traffic, depending on the type of line being placed. Arrowboard requirements are detailed in the "Field Manual" of the *Minnesota Manual of Traffic Control Devices*. Also, truck equipment shall be capable of accumulating the footage applied per gun, individually each day. Only material application shall activate the footage accumulators. The readout shall be digital and not adjustable.
- 5.1.3 The equipment shall be capable of applying glass beads in a pressurized system at a rate of at least 3.0 kg/L (25 lb./gal.). **A greater bead application rate may be necessary for meeting the performance criteria (minimum levels of retroreflectivity). This will require contractors to consult with all the material manufacturers.**
- 5.1.4 All guns on the spray carriages shall be in full view of the operator(s) during operation.
- 5.1.5 Each crew shall include at least one technical expert knowledgeable in equipment operation, application techniques, control of traffic, and safety regulations.

5.2 Procedures

- 5.2.1 Pavement markings shall be placed in accordance with the details shown in the Plans and the control points established by the Engineer.
- 5.2.2 The road surface shall be cleaned at the direction of the Engineer just prior to an application. Pavement cleaning shall consist of at least brushing with a rotary broom (non-metallic), or as recommended by the material manufacturer and acceptable to the Engineer. New Portland cement concrete surfaces shall be sandblasted clean to remove any surface treatments and/or laitance. On low speed [Speed Limit 65 km/h (40 mph) or less] urban portland cement concrete roadways, sandblast cleaning shall be used for all epoxy pavement markings.
- 5.2.3 If the roadway surface is dry, the epoxy material application shall immediately follow the pavement cleaning and be preceded by an air blast. However, markings shall not be applied when the wind or other conditions cause a film of dust to be deposited on the pavement surface before the material can be applied.
- 5.2.4 The Engineer will place necessary spotting at appropriate points as overall horizontal control for striping and to indicate necessary starting and cutoff points. Broken line intervals will not be marked. Longitudinal joints, pavement edges, and existing markings shall serve as control points when so directed.
- 5.2.5 A 380 μm (15 mil) epoxy line requires a liter of mixed components for every 25.8 m (84.5 ft.) of 100 mm (4 in.) wide line. Field measurements are inserted into the following equation: Line Thickness in micrometers = Liters \times 0.001 \times 10^{-3} \times m^3 divided by the quantity Length in meters \times width in meters (Thickness in inches = Gallons \times 231 cubic inches divided by the quantity Length (inches) \times Width (inches)). Use 3.785 liters per gallon if epoxy is metered in gallons.

- 5.2.6 The minimum line width shall be its nominal width with 6 mm (¼ in.) greater than the nominal width allowed provided the variation is gradual and does not detract from the general appearance. Broken line segments, normally 2 m (6.56 ft.) every 10 m (32.81 ft.), may vary up to 75 mm (3 in.) from the specified lengths provided the over and under variations are reasonably compensatory. Alignment deviations from the control guide shall not exceed , except when approved by the Engineer. Material shall not be applied over a longitudinal joint. Establishment of application tolerances shall not relieve the Contractor of his responsibility to comply as closely as practicable with the planned dimensions.
- 5.3 Spraying Operation
- 5.3.1 Placement of epoxy materials shall be permitted only on a clean, dry pavement surface and air and pavement temperatures at least 10° C (50° F) unless the manufacturer, in writing, approves a lower temperature.
- 5.3.2 Two parts of epoxy component A (pigment) and one part component B (hardener) shall be heated separately at 43°±1° C (110°±30° F) and thoroughly mixed. All material heated over 60° C (140° F) shall be discarded. The sprayed epoxy shall be applied at 43°±1° C (110°±30° F) **or as recommended by the manufacturer.**
- 5.3.3 Glass beads shall be applied immediately after the placement of the epoxy. If two bead gradations are required by the Special Provisions, two bead dispensers are required to deliver the specified drop rates. Otherwise the dispenser system must deliver at a minimum 3.0 kg (25 lb./gal.) of beads per liter of epoxy material. **A greater bead application rate may be necessary for meeting the performance criteria (minimum levels of retroreflectivity). This will require contractors to consult with all the material manufacturers.**
- 5.3.4 The Contractor shall cooperate with inspection personnel in reviewing operation of the equipment, safety precautions, measurement of materials (components and beads), computations to determine specific and daily application rates, sampling materials, making other measurements, such as epoxy thickness, and notifications as to work schedule.
- 5.3.5 **Only Type II epoxy material shall be used for epoxy pavement markings except when specified as otherwise in the Special Provisions.**
- 5.3.6 Traffic control for the pavement marking operations shall be in substantial conformance with the “Field Manual,” *Minnesota Manual of Uniform Traffic Control Devices* . **A shadow vehicle with a truck-mounted attenuator shall be used on high speed [SPEED LIMIT (65 km/h) (40 mph) and greater], high volume (ADT 1500 and greater) highways.**

6.0 SAMPLING RATE & PROCEDURES

- 6.1 One pint samples of each manufacturer’s lot or batch furnished for the contract shall be **submitted to Mn/DOT at the time of manufacturing.** One pint samples of both Part A (yellow/white) & part B must be submitted to the Mn/DOT Materials Laboratory, 1400 Gervais Ave., Maplewood, Minnesota 55109. (612) 779-5550 or 5549, FAX: (612) 779-5616. Samples shall be identified as follows:
- | | | | |
|----|-------------------------------|----|---------------------------------|
| 1. | Manufacturer's Name | 5. | Color |
| 2. | Manufacturer's Product Number | 6. | Intended state project numbers. |
| 3. | Lot/Batch Number | | |
| 4. | Date Manufactured | | |
- 6.2 Contractors will not be allowed to use material that has not meet the requirements of Sections 6.1 & 7.0. Contractors will be asked to remove material that does not conform to Sections 6.1 & 7.0 and replace with material that does.

7.0 CERTIFICATIONS

- 7.1 The manufacturer shall certify that the components meet the requirements of these specifications and are on the Mn/DOT Approved Product List.
- 7.2 Certifications shall be sent along with the samples in section 6.1.

8.0 CONTAINER MARKINGS

- 8.1 Containers for epoxy components shall be marked with the manufacturer's name, product identification number, lot or batch number, date of manufacture, color, net weight of contents.
- 8.2 Containers for glass beads shall be marked with the name of manufacturer, the wording "Glass Beads," lot or batch number, coating type, date manufactured, and the net weight.

9.0 ACCEPTANCE OF PAVEMENT MARKINGS

In order to be a long-life pavement marking, epoxy markings placed in Minnesota must retain a satisfactory level of retroreflectivity in addition to demonstrating good adhesion, resisting chipping, and exhibiting proper daytime and nighttime colors. These attributes have been observed and evaluated for several years and are the basis for acceptance/rejection procedures and values used herein.

- 9.1 Retroreflectivity
- 9.1.1 Acceptable Minimum Retroreflectivity Values

MINIMUM AVERAGE RETROREFLECTIVITY VALUES FOR EPOXY MARKINGS (mcd/m²/lux)

<u>Period</u>	<u>White</u>	<u>Yellow</u>
Initial*	300	200
After-One-Winter*	175	140

* Described in Section 9.1.4 Miscellaneous Traffic Controls, Numbers 4 and 5.

- 9.1.2 Retroreflectometers-- Measurements shall be taken with either a portable or mobile retroreflectometer conforming to 30-meter geometry which is defined as: the entrance angle (the angle between the illumination axis and the retroreflector axis) shall fall between 88.50° and 88.76° and the observation angle (the angle between the illumination axis and the observation axis) shall fall between 1.0° and 1.05°; and, the co-viewing angle (the complement of the entrance angle) shall fall between 2.29° and 2.50°. All retroreflectivity readings and data analysis will be provided by Mn/DOT at no cost to the Contractor. Mn/DOT reserves the right to:
- make daytime and/or nighttime visual inspections with or without the presence of the Contractor's representative, mainly to locate obvious or suspect areas of deficiency, and
 - determine retroreflectivity of symbols, legends and lines wider than 200 mm (8 in.) using the portable retroreflectometer only.
- 9.1.3 Test Segments -- The following methodology will be used to evaluate retroreflectivity performance of in-service longitudinal line pavement markings:

LENGTH AND NUMBER OF TEST SEGMENTS^a PER ROADWAY^b PER LINE TYPE^c

Length of Roadway	Number of Test Segments	Length of Test Segments
Less than 1.5 km (1 mi.)	1	300 m (0.2 mi.)
Greater than or equal to 1.5 km (1 mi.)	1 per 1.5 km (1 mi.)	300 m (0.2 mi.)

- ^a TEST SEGMENTS-- Areas of a roadway chosen for measuring retroreflectivity of the line types.
- ^b ROADWAY--As used here, means that portion of a street or highway ordinarily used for vehicular traffic. In the event a street or highway includes two or more separate roadways, the term roadway shall refer to each roadway separately.
- ^c LINE TYPE-- Longitudinal lines of the same color and function. For example, white and yellow edge lines are each a line type.

9.1.4 Measurements in Test Segments

Portable Retroreflectometer

1. Take a minimum of 20 readings in each test segment per line type.
2. On broken lines (skip striping), measure every other stripe, taking no more than two readings per stripe with readings 0.5 m (20 in.) from the ends of the marking.
3. For solid lines, divide test segment into ten areas of 30 m (100 ft.); space readings a minimum of 10 m (33 ft.) and a maximum of 30 m (100 ft.) apart.
4. For 10 percent of each message type, take 5 readings on each message line; for 10 percent of each symbol type, take 5 readings on each symbol.
5. Upon completion of the evaluation, regardless of the results, additional test segments may be ordered by the Engineer.

Mobile Retroreflectometer

1. Calibration of the instruments shall be in accordance with the manufacturer's instructions.
2. Retroreflectivity shall be measured at a minimum rate of 20 percent of each roadway length by line type.
3. Should another mobile unit be available, the maximum acceptable deviation for measurements made by the two different instruments of the same manufacturer and for the same roadway length shall be $\pm 10\%$.
4. Repeatability for the given mobile unit shall be $\pm 6\%$.
5. Upon completion of the evaluation, regardless of the results, additional test segments may be ordered by the Engineer.

Miscellaneous Controls

1. Take measurements on a clean, dry roadway.
2. Collect data in direction of traffic flow.
3. Measurement units are: mcd/m²/lux.

4. Wait at least two (2) weeks from date of placement of the markings before taking initial readings.
5. Take after-one-winter readings in May or June to assure that spring rains have cleaned the beads.
6. Randomly select test segments unless night reviews or other knowledge supersedes a random selection process.
7. Measure each line type separately.
8. The Engineer may request additional readings or test segments.
9. In the event LASERLUX is not available, the Engineer may require the use of the portable retroreflectometer or establish an alternative evaluation plan.

9.1.5 Contents of Retroreflectivity Report

The report shall consist of:

- State Project number
- Trunk Highway number
- Test date
- Geographical location of the test site(s), including distance from the nearest permanent site identification, such as a reference point.
- Identification of the pavement marking material tested: type, color, age, and transverse location on the road
- Identification of the retroreflectometer
- Remarks concerning the overall condition of the line, messages and symbols such as carryover of asphalt, snow plow damage, uneven distribution of beads, etc.
- Average of the readings for each test segment with one standard deviation calculated.
- Average of the readings for each message and symbol type.

9.2 Correction of Defects/Penalties

1. All pavement markings not conforming to the requirements of the Contract shall be removed and replaced or otherwise repaired to the satisfaction of the Engineer. Removal of unacceptable work shall be accomplished with suitable blasting or grinding equipment unless other means are authorized by the Engineer.
2. Where yield computations show a deficiency in material usage of not more than 20 percent, Mn/DOT may require satisfactory repair or may accept the work at a reduced unit price which is in direct proportion to the percent of the deficiency. Where the deficiency in material usage exceeds 20%, Mn/DOT may require removal and replacement to the satisfaction of the Engineer unless other means are approved by the Engineer.
3. If the Engineer requires removal and replacement, the contractor shall remove (by an approved process) at least 90% of the deficient line, with no excessive scarring of the existing pavement. The removal width shall be one inch wider all around the nominal width of the pavement marking to be removed.

4. Where initial retroreflectivity falls below the minimum acceptable levels but not more than 20%, the Engineer may require satisfactory repair or may accept the work at a reduced unit price which is in direct proportion to the percent of the deficiency. Where the deficiency in retroreflectivity exceeds 20%, i.e., less than 240 mcd/m²/lux for white and 160 mcd/m²/lux for yellow, the Engineer may require the removal and replacement to the satisfaction of the Engineer unless other means are approved by the Engineer. Where minimum levels after one winter fall below the specified levels (170 mcd/m²/lux - 135 mcd/m²/lux), Mn/DOT will notify the project contractor and manufacturer(s) of the failure. If the initial readings were above Mn/DOT's specified initial minimum levels (300 mcd/m²/lux - 200 mcd/m²/lux), the Engineer, contractor, and manufacturer(s) of the material(s) shall review the project together. Based on the review an of all known aspects, the Engineer will make a determination as to why the job failed and notify the Contractor, pavement marking contractor, and/or manufacturer(s) in writing.
5. If this process has to be repeated on several projects with either the same contractor and/or manufacturer(s), Mn/DOT will take corrective action. This corrective action will be a two step process:
 - Step 1 Pavement marking contractor/manufacturer(s) will be considered not approved for Mn/DOT projects, except to bring workmanship/product back into compliance.
 - Step 2 If the first step cannot be attained, pavement marking contractor/manufacturer(s) will not be allowed to participate in Mn/DOT projects and/or be removed from Approved Product List.

10.0 DOCUMENTATION

Contractors applying epoxy pavement markings for Mn/DOT under a contract ~~are required~~ to fill out the attached "Construction Striper Operations Daily Log" form. These forms shall be completed at the end of each project and faxed to the "Reflective Systems Unit" at (612) 797 3181 Attn: Jim Carlson. ~~Failure to submit completed forms may result in 10% of the overall contract price for epoxy pavement markings held back.~~ Also, if forms are not sent in to the reflective systems unit in a timely manner projects will not be inspected during optimum times for meeting their performance criteria. Any questions regarding this form can be answered by calling the Reflective Systems Unit at (612) 797 3183.

S-262.1 Section 10.0 of the attached "Specification for Epoxy Resin Pavement Markings" is hereby deleted and the following substituted therefore:

Contractors applying epoxy pavement markings for Mn/DOT under a contract are required to fill out the attached "Construction Striping Report" form. These forms shall be completed at the end of each project. The original shall be given to the Engineer. Failure to submit completed forms may result in 10% of the overall contract price for epoxy pavement markings held back. The Engineer will fax them "ATTN: Pavement Marking Engineer" at 651-234-7370. If forms are not sent in to the reflective systems unit in a timely manner projects will not be inspected during optimum times for meeting their performance criteria. Any questions regarding this form can be answered by calling the Pavement Marking Engineer at (651) 234-7373. The form is on the website at:
<http://www.dot.state.mn.us/trafficeng/products/ContractorStripingDailyReportForm.doc>

