Durable Pavement Marking and Grooving

Final Report
April 2018

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16. Abstract

Maintaining effective pavement markings year-round is a challenge in Iowa, where winter maintenance causes so much damage due to the harsh winter exposure from snow plow blades, sand, and salt brine. Given these conditions, and a limited painting season, it is critical that agencies select the proper pavement marking materials for the roadways in their network.

The overarching objective of this work was to support the Iowa Department of Transportation (DOT) Pavement Marking Task Force (PMT) in achieving better pavement markings statewide.

While the initial scope of this project was to evaluate different durable markings and pavement grooving configurations in an effort to make better choices for year-round markings, limited funding, difficulty in finding a contractor for a small test site, and adverse weather conditions caused the project to be revised to omit the field evaluation.

Instead, the project focused on supporting PMT decision making in light of challenging financial conditions, and particularly supporting efforts to determine paint truck and material choices by looking at peer states, and also by looking at contracting options for installation on the state system.

Pavement markings play a critical role in guiding motorists and delineating roadways for safe travel. The identification and use of more durable pavement markings may be the key to improving visibility, operations, and—most importantly—safety.

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DURABLE PAVEMENT MARKING AND GROOVING

Final Report
April 2018

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INTRODUCTION

Pavement markings play a critical role in guiding motorists and delineating roadways for safe travel. The identification and use of more durable pavement markings may be the key toward improving visibility, operations, and most importantly, safety. Maintaining effective pavement markings year-round is a challenge in Iowa given the harsh winter exposure from snow plow blades, sand, and salt brine. The limited painting season also adds to the need to select the proper pavement marking materials for the roadway network. For example, where should you use regular paint, which may not last over the winter, as opposed to a more expensive durable marking product?

The Iowa Department of Transportation (DOT) Pavement Marking Task Force (PMT) is interested in addressing overall pavement marking performance issues, such as installation, equipment needs, standardization, retroreflectivity monitoring, and materials selection.

This report summarizes pavement marking-related support activities provided to the PMT under the Iowa Highway Research Board (IHRB) Project TR-652 as follows:

1. TR-652 Durable Pavement Marking and Grooving: This contract was established to evaluate different durable markings, as well as pavement grooving configurations in an effort to make better choices for year-round markings. However, after developing the test deck layout and measurement methodology, the separate Iowa DOT funds necessary for installation were not available. In addition, the weather conditions at the time were such that contractors were scrambling to get their roadway striping work completed and had little incentive to bid the minimal quantities called for on the test deck. Based on these unforeseen issues, the PMT asked to revise the project and omit the field evaluation but to add a focus on several pressing issues faced at the time.

2. TR-652 (revised) Analysis of Statewide Pavement Marking Program: This contract revision focused on supporting PMT decision making in light of challenging financial conditions. More specifically, this effort supported efforts to determine long-line paint truck choices, material choices through consideration of other peer states, and contracting options for installation on the state system.

OBJECTIVE

The overarching objective of this work was to support the PMT in achieving better pavement markings statewide.

PROJECT ACTIVITIES

Durable Pavement Marking and Grooving

The project Technical Advisory Committee was the Iowa DOT Pavement Marking Task Force (PMT) chaired by John Hart. The project scope included the below tasks with the objective being to evaluate different grooved-in durable pavement markings.

1. Technical Advisory Committee

2. Durable pavement marking field evaluation

3. Grooving field evaluation

4. Analysis

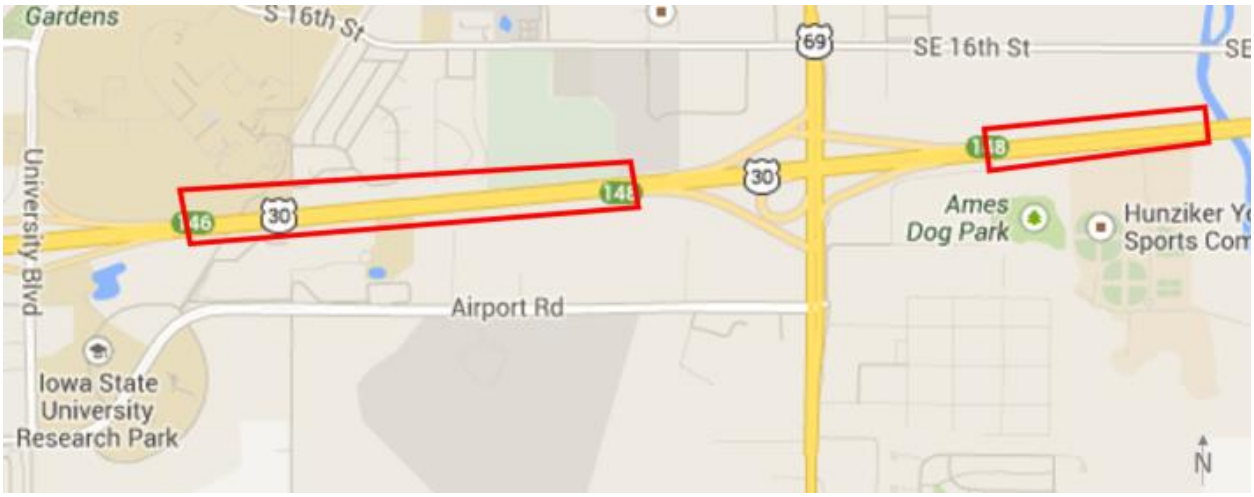
5. Final report

Methodology

Given that the field evaluation will provide contrast between the different durable pavement marking products as exposed over a two-year time period, the research team worked carefully with the PMT to establish a clear and efficient test methodology covering location, setup, materials, evaluation methodology, and reporting requirements as follows.

Test Deck Location

The PMT provided input regarding a number of test deck locations within the state and had discussions contrasting traffic volumes, number of lanes, ease of installation and measurement (safety), and condition of the existing pavement surface. Ultimately, the recently paved US 30, within Ames, was identified as the preferred test location. This section of US 30 between University Boulevard and South Skunk River is shown in Figure 1(testing would be in both directions of travel).



Map data ©2014 Google

Figure 1. Test deck location along US 30 Ames

Potential Materials

The PMT was interested in evaluating the following pavement marking materials:

- Waterborne (latex)
- Epoxy
- Thermoplastic
- High Build Waterborne with Visilok (drying agent)

Evaluation Details

In an effort to simplify material evaluations, the following evaluation details were established:

- Pavement surface would be asphalt only, for comparison of durable materials
- Only four-lane roadways and only the White Edge Line (for safety)
- Glass bead packages will not be specified, allowing vendors to determine best performing
- Glass media would not include all weather (wet) elements/beads
- Groove depths include 3 levels (surface prep only, 80 mil, and 120 mil)

Measurement Methodology

Based on input from the PMT, the field evaluation methodology developed for each test section (varying materials and groove depths) includes use of a hand-held retroreflectometer to take readings continuously every 50 feet along the white edge line following ASTM 1710. Measurement frequency includes initially (within 20 days of installation), after 1 winter, and after 2 winters.

Evaluation Sections

Imagery ©2014 Google, Map data ©2014 Google

Figure 2 identifies the five test sections planned along US 30 in Ames (on each side of the Duff Avenue interchange). Each section is 2,000 feet in length and will have 400 feet of surface applied material (after existing paint removed), 800 feet of material applied in a 80 mil groove, and 800 feet of material applied in a 120 mil groove. The materials to be applied include: Latex, Highbuild, Epoxy, and Thermoplastic. DOT District 1 would provide traffic control for the test deck installation and will install the durable latex paint portion of the test deck.

Figures 3 through 7 include details by section specific to product, sub-segment lengths, groove depths, and the anticipated party for installation.

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Figure 2. US 30 evaluation sections

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Figure 3 provides the evaluation details for Section 1.

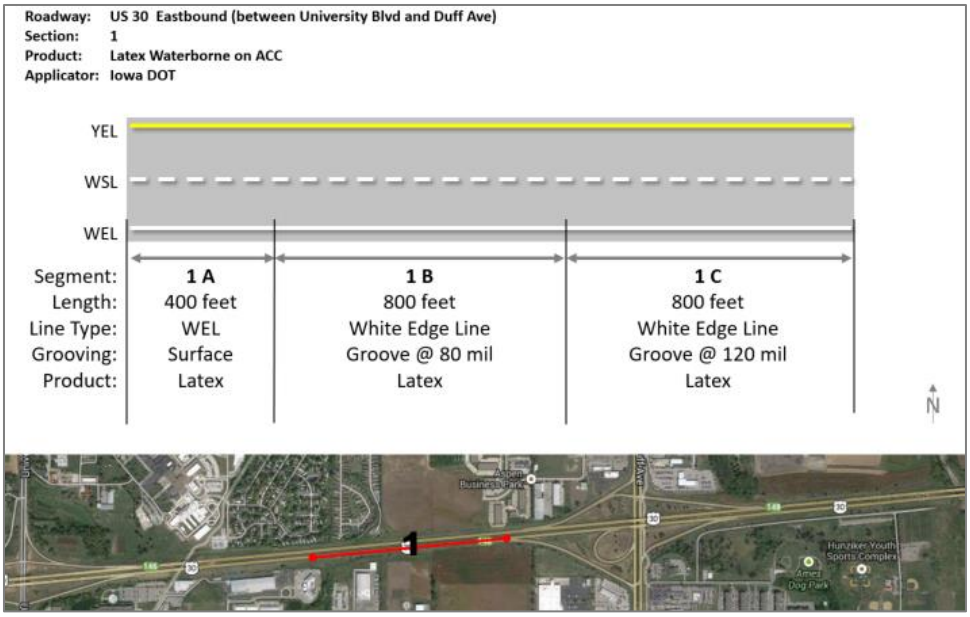

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Figure 3. Section 1 details

Figure 4 provides the evaluation details for Section 2.

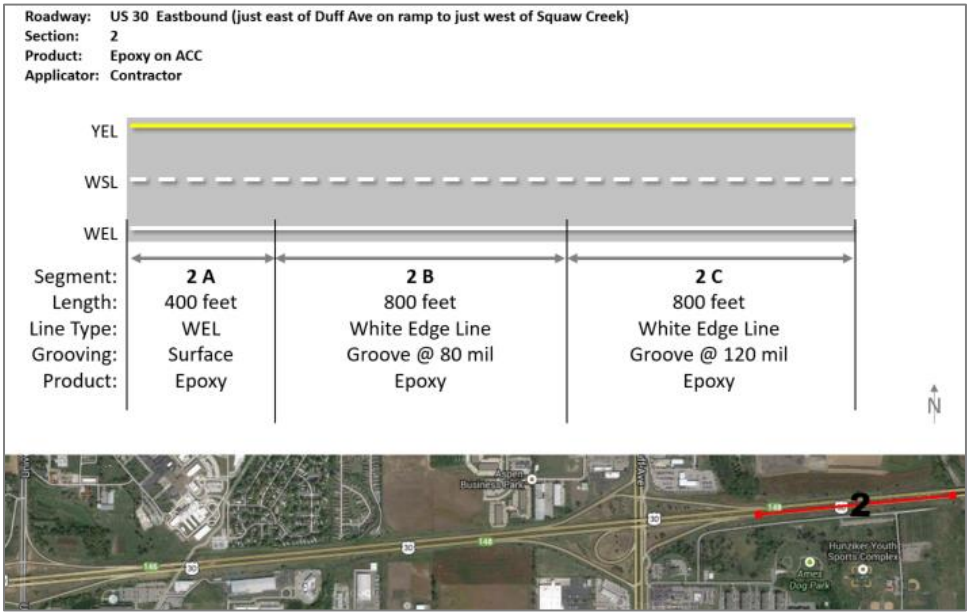

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Figure 4. Section 2 details

Figure 5 provides the evaluation details for Section 3.

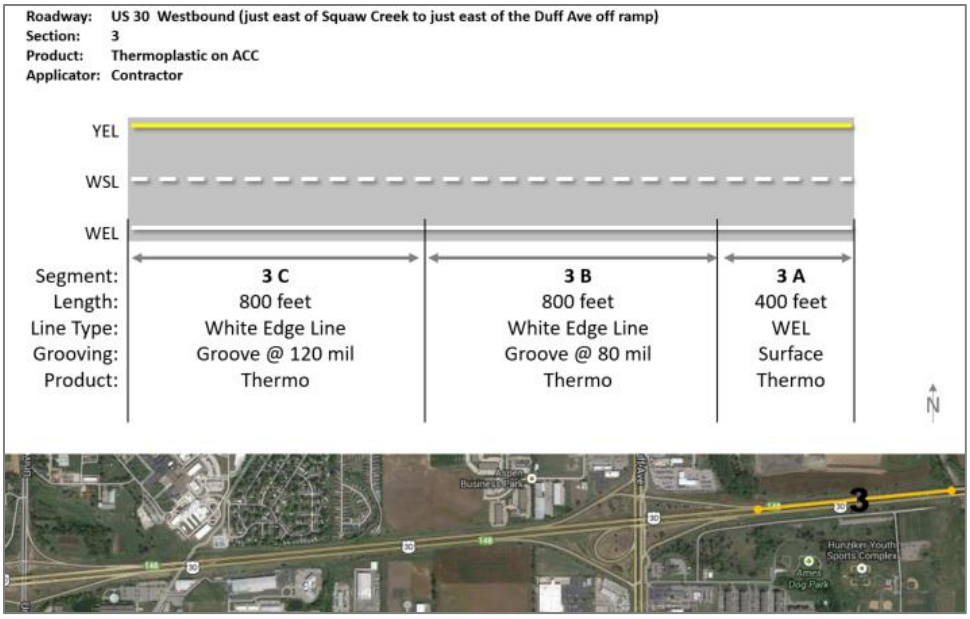

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Figure 5. Section 3 details

Figure 6 provides the evaluation details for Section 4.

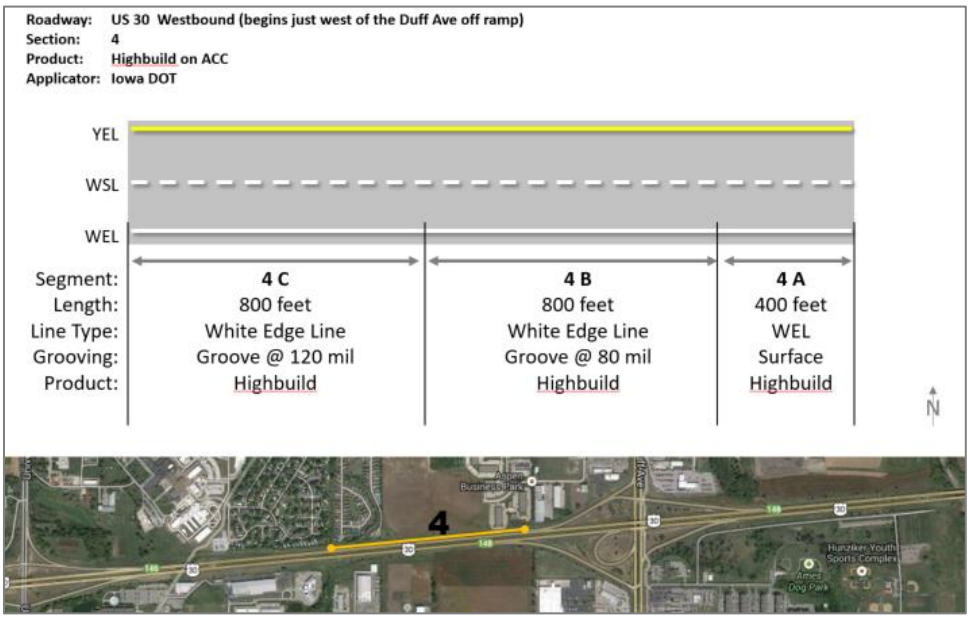

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Figure 6. Section 4 details

Figure 7 provides the evaluation details for Section 5.

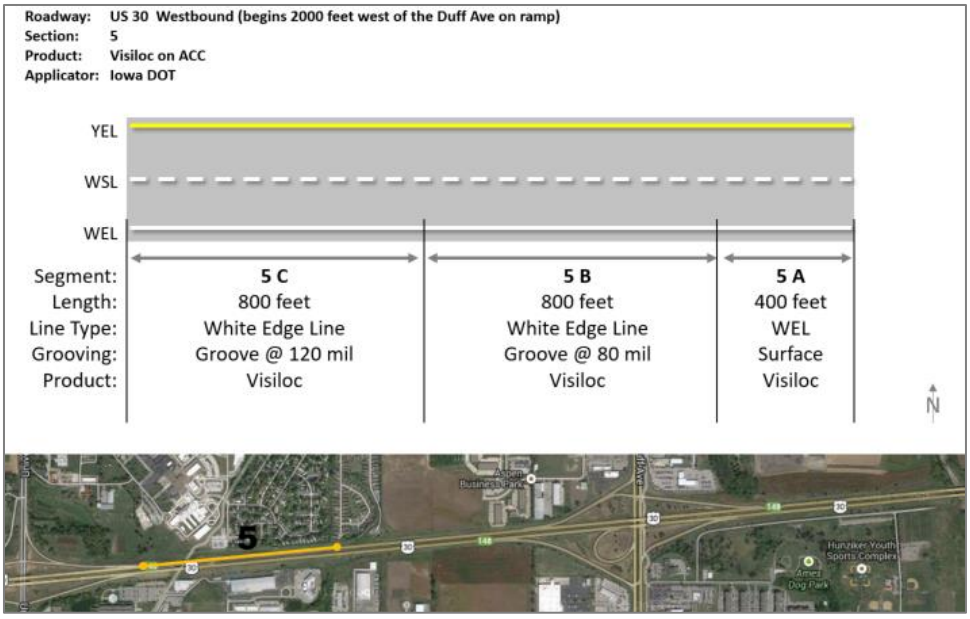

Figure 7. Section 5 details

Surface Preparation and Grooving Quantity

Details specific to surface preparation include:

- Removal of existing markings (2,000 feet total, which is 400 feet per section)
- Grooving at 80 mil (4,000 feet, which is 800 feet per section) 5-inch width using diamond blades
- Grooving at 120 mil (4,000 feet, which is 800 feet per section) 5-inch width using diamond blades

Installation Issues Faced

The project scope noted that the cost of the installing the test deck would be covered separately by DOT (*This proposal expects the Iowa DOT to cover the cost of materials, installation, and traffic control included in the field experiments*). However, as the project progressed, the PMT realized that including this work within the DOT specification, which required a bid process, would be difficult given the very low quantities of materials involved.

Ultimately, the team was unable to get a contractor interested in bidding and agreeing to complete this work (over two seasons 2014/2015). The reasons given include that they are too busy with their contract striping activity, don't want to mobilize and complete this work for such

low quantities, and do not have all the equipment necessary to complete both the grooving and durable marking installation.

The completed work reflected less than 10 percent of the project budget with the following work completed:

- TAC meetings and administrative actions
- Selection process and final selection of a test deck location (US 30)
- Development of a testing methodology
- Determination of quantities
- Working with the Institute for Transportation (InTrans) finance specific to bidding procedures
- Communications with District 1 maintenance relative to traffic control
- Communications and presentations with local area contractors specific to requests for bids

Project Termination and Repurposing

Based on the research team's conversations with PMT, a decision was made to terminate the test deck research effort (not extend for more years) and to take advantage of some work that the Center for Transportation Research and Education (CTRE) has done in another state to consider the role that durable markings may have for pavement markings in Iowa. In addition, the PMT was facing some new challenges related to equipment and statewide operations that needed addressed, as was the focus of the revised project effort.

Analysis of Statewide Pavement Marking Program

This work focused on supporting decision making by the PMT in light of ever more challenging financial conditions and performance constraints. This includes work within several pavement marking priority areas:

- Delivery methods and quality assurance
- Equipment
- Optimization, coverage, and levels of service

- Data collection and evaluation
- Research needs
- Training needs

The project scope included the following tasks:

1. Technical Advisory Committee
2. Analysis
3. Final report

Specific support activities under Task 2 (Analysis) were directed by the PMT and are summarized below. This overall document serves as Task 3 (Final report).

State DOT Pavement Marking Practices

Minnesota DOT

The PMT wanted to understand the pavement marking practices of the Minnesota DOT (MnDOT) given their harsh winter conditions and shorter annual painting season. To accomplish this, the research team prepared questions in advance and worked with MnDOT staff to organize a conference call. Information from the technical exchange on April 20, 2016 between MnDOT, the PMT members, and all of the Iowa DOT District Maintenance Managers follows.

Statewide Pavement Marking Equipment:

- Five latex trucks
- Two epoxy trucks
- Two signing crews

Central Striping (CS) Organization:

- Each district has a representative on a board of directors and districts are customers and owners
- Next month will receive new MRL striper $800,000 plural component (epoxy) 2:1

- Central Striping charges districts for the striping work done

- Each spring district sends striping plan to CS

- Assemble materials and decide how work divided up among crews

- Two epoxy, five latex with crews being district people but in summer come to central striping funding (bid onto this and have to be qualified) then go all over the state

- Built into the prices charged is a fund to replace equipment

- Traffic office is in charge of striping standards and material choices (what districts have to follow). Whatever the districts determine to stripe, they do it and it is up to each district to decide between epoxy and latex.

- Have a $2 million per year fund. CS bills districts for striping and agreed to by district representatives on executive board. Divide funds by line in each district. Have a business plan regarding when will replace equipment.

Materials:

- Paint and beads cost approximately $3 million per year. Put out for bids (two-year contract with an option to renew annually for three years). Blanket purchase order (PO) per year with crew leaders calling in and ordering paint and beads to be delivered where they need it.

- Currently latex comes from Vogel, beads are Potters

- Do about 11,000 line miles of latex per year

- Do about 4,000 to 5,000 line miles of epoxy per year (modified urethane)

- Have about 36,000 to 38,000 line miles in the state. Less than one-third is latex

- Put down quite a bit of wet reflective element in high-build latex

- CS does not groove the pavement themselves. Looked into this but done as part of construction (they are in maintenance). For CS, 98 percent of what they put down are maintenance lines.

- Traffic office comes up with standard of what to apply based on annual average daily traffic (AADT), etc. (when choosing latex versus epoxy. If varies, have to ask for variance.)

- HPS4 is what they initially began with; however, this can be a little bit more abrasive (have to rebuild their pumps). MFUA-10 is also on their products list and now both compete on price and are assumed similar.

Equipment Procurement:

- CS develops truck specifications based on input from central shop, crew leaders, and mechanics. Then, all vendors (MRL, EZLiner, and MB). Equipment specifications are then put out for bid and they take the lowest cost comparable bid.

- Currently, both epoxy trucks are MRL and all latex trucks are EZ-Liner.

- All of their trucks paint off the back. With latex they do two lines at once. Not with epoxy as HPS4 needs different pressure and temperature on yellow versus white so they just shoot one line. While there are two seats in the back, they typically just have one operator back there. In contrast, with latex they use two operators in the back.

Material Performance:

- Epoxy typically lasts three to five times longer than latex. Latex life expectancy is typically about one year unless on a rural road.

- CS reapplies epoxy back on top of epoxy.

- Each district has a striping coordinator who determines what product is painted over the existing marking.

- In the past, each district was doing their own striping (11 latex trucks) and they had just purchased two epoxy stripers. They experienced some variability in production statewide.

- Now they track crew productivity using a daily log (skip line controller).

- CS has a meeting at the beginning of the season to talk about the previous season, production, and based on this, each crew is assigned a price per foot (metro district being the exception).

- Every crew has at least one truck following except for epoxy and within the Metro where they use two. They use a special cone truck for epoxy (part of shared equipment).

Issues:

- CS does not experience a significant number of claims annually (about 100 paint claims per year with around 50 percent dismissed outright).

- Painting operations crashes do occur but CS has not had one for two years. Usually, it is the crash cushion that gets hit, with one exception where the paint carriage was struck.

- Of the seven long-line crews, three are supervised by someone that works for CS with the others supervised from district.

Traffic Control:

- If painting centerline, their traffic control may depend on what type of shoulder exists. If the shoulder is in good condition, they will direct traffic to shoulder; if not, they will direct traffic off to the other lane for short time then get off the road to let traffic clear out. CS works this out ahead of time with each striping coordinators and sub-area supervisor.

- MnDOT traffic control designs for striping operations are available.

Equipment life:

- Years ago they had 20-plus year truck life; however, now use 15- to 20-year life and then run these out to 20 years.

- Painting over existing stripes: Last latex truck ordered has a system on it for putting wet reflective elements down. This is the first year to renew these wet reflective lines with two districts wanting to do this. This year have:

    - 300 line miles latex with wet elements

    - 60 line miles of epoxy with wet elements

    - Qualified Products List (QPL) includes wet reflective elements. These go in a milled in surface and the groove should accommodate at least one restripe without hitting the surface.

Paint Operations:

- Surface preparation includes blowing compressed air on existing surface, and they make sure that each truck has good air pressure

- Wet mil thickness is 12 mil on everything (latex and epoxy)

- Truck paint speed is approximately 9 to 14 mph, depending on what they are doing

Approximate Paint Costs:

- $0.05 per foot latex (covers all their costs)

- $0.15 per foot epoxy (covers all their costs)

- $0.177 per foot wet reflective latex (not including the groove)

- $0.389 per foot wet reflective epoxy (not including the groove)

Painting Rumble Stripes:

- CS has found that the rumbles fill up with lots of road grime. These are painted like any other line. The paint carriages can straddle the rumble so there are no issues with vibration. They typically apply latex on rumbles but can do both epoxy and latex depending the district decision.

Kansas DOT

The PMT also acquired information specific to durable pavement markings in Kansas based on their Special Provision to the Standard Specification, 2015 Edition Section 806 Durable Pavement Marking. Relevant points of interest included:

- Wet Weather Beads. Prior to any roadway application, the manufacturer shall submit a letter of certification stating that their glass beads have been tested and approved for wet weather pavement marking applications. The letter should state what classification the wet weather beads will be considered for use either for wet recoverable or wet continuous applications. The Engineer will use this letter as the basis of acceptance.

- Contractor's Personnel. Provide a minimum of one employee on the project holding an American Traffic Safety Services Association (ATSSA) pavement marking certification and experienced in the application of the appropriate type of pavement marking material.

- Pavement Marking Contractors. Provide a letter of certification from the pavement marking manufacturer indicating the contractor's qualifications to install their product.

- Test Strip. Before beginning pavement marking operations, at a location approved by the engineer, complete a 300-foot test section for epoxy, thermoplastic, sprayed thermoplastic and multi-component pavement markings that meet the requirements of this specification.

The engineer will inspect the test strip 24 hours after it has been placed. Do not begin pavement marking operations until the engineer approves the test strip.

- Minimum retroreflectivity requirements (Table 806-1). If the pavement markings have a retroreflectivity reading as measured for Table 806-1 (in any 1 mile section) less than that shown in Table 806-2, remove and replace the entire one-mile section.

- Durable pavement marking retroreflectivity deduction (Table 806-4).

Illinois DOT

The PMT acquired information specific to durable pavement markings in Illinois based on the Pavement Marking Selection, Installation and Inspection Manual, August 1, 2015. Relevant points of interest included marking materials. Illinois DOT-approved permanent pavement marking materials for long-line application are:

- Thermoplastic

- Water-based paint

- Preformed plastic (tape), Type B

- Epoxy

- Polyurea

- Modified urethane

Illinois DOT matrix of marking material compatibility for restriping (Table 1).

Guidelines on the use of pavement marking materials on state highways Section 780 Pavement Striping http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Construction/Standard-Specifications/Standard%20Specifications%20for%20Road%20and%20Bridge%20Construction%202016.pdf

Wisconsin DOT

The Wisconsin DOT's prequalified product partial list (at http://wisconsindot.gov/Documents/doing-bus/eng-consultants/cnslt-rsrces/tools/appr-prod/ap2016/pavement-marking-2016f.pdf) includes the following:

- Pavement marking
- Waterborne paint
- Epoxy
- Reflective epoxy elements
- Wet reflective tape

Other DOT Reference Materials Reviewed

- Indiana DOT Pavement Traffic Markings at http://www.in.gov/indot/files/HAChapter_11.pdf
- Oregon DOT Pavement Marking Design Guidelines at http://www.oregon.gov/ODOT/Engineering/Documents_TrafficStandards/Pavement-Marking-Design-Guide.pdf
- CalTrans Guideline for Selecting Materials and Standard Special Provisions for Traffic Striping and Pavement Marking at http://www.dot.ca.gov/hq/esc/ttsb/chemical/pdf/Striping_GuidelineVer2.pdf
- Colorado DOT draft Pavement Marking Selection Guidelines (pdf only)
- Oklahoma DOT draft Pavement Marking Selection Guide (pdf only)
- Texas DOT Material Selection Guide from Pavement Marking Handbook at onlinemanuals.txdot.gov/txdotmanuals/pmh/material_selection_guide.htm

Iowa DOT Program Considerations

Durable Markings on Multi-Lane High-Volume Roadways

Iowa DOT crews use waterborne paint for their long-line operations, and this typically requires annual restriping. The DOT wants to consider their options toward a more durable product, particularly on the higher volume multi-lane roadways. This included consideration of locations, pavement marking line types to stripe, durable materials to use, retroreflectivity levels, and installation method.

Durable Marking Locations

The PMT considered several statewide strategies for placement of durable pavement markings ultimately ending with a focus on interstate roadways. This was based on the premise that interstate roadways serve the highest vehicle and truck volumes, have the highest speeds, and are the most problematic for state crews to stripe. There are considerable mobility and safety advantages to striping these roads every three years as opposed to annually.

The team understood that a statewide approach is desirable but that a durable program would need to be phased in given an initial projection for all interstates that totaled over $12 million as shown in Table 1.

Table 1. Statewide durable pavement marking cost consideration

STATEWIDE SCENARIO					
Interstate Route Number	Route Description	Length (miles)	Approx. Length Both Directions	Estimated Cost ($/Mile)	Est. Cost
29	From the Iowa-Missouri state line	151.82	304	$ 5,500	$ 1,670,020
35	From the Iowa-Missouri state line	218.446	437	$ 8,600	$ 3,757,271
74	From the Iowa-Illinois state line at	5.386	11	$ 8,600	$ 92,639
80	From the Iowa-Nebraska state line	288.933	578	$ 8,600	$ 4,969,648
129	From a junction with I-29 south of	0.283	1	$ 5,500	$ 3,113
235	From a point on I-35 in West Des M	13.847	28	$ 8,600	$ 238,168
280	From the Iowa-Illinois state line so	9.577	19	$ 5,500	$ 105,347
380	From a junction with I-80 near Iow	73.097	146	$ 8,600	$ 1,257,268
480	From the Iowa-Nebraska state line	0.722	1	$ 5,500	$ 7,942
680	Route consists of two sections: fir	19.693	39	$ 5,500	$ 216,623
				Total=	$ 12,318,040

The PMT understood that costs would vary considerably based on quantities and actual bid prices. Understanding that the use of durable markings is not prevalent, a demonstration project was proposed as a logical beginning point.

Durable Marking Line Types and Roadway

The PMT considered a couple of different striping scenarios that included:

- With Grooving: This includes both the white and yellow edge lines to be surface applied and the white skip line to be placed within a groove with wet reflective media added.

- No Grooving: All interstate line types would be surface applied with no wet reflective media included.

- Both scenarios involve only interstate long-lines, no ramps, nor gore areas, etc.

After discussing the installation and staging details for each option, it was determined that the grooving option was not feasible for the demonstration because it would leave the lane without a permanent marking for short periods of time, and this is not acceptable to the DOT without a full lane closure. Closing a lane to complete the grooving was not desirable. Other DOTs, like Illinois, do in fact groove in pavement markings; however, the grooving is completed as part of roadway resurfacing projects and not as a maintenance striping process.

The PMT also determined that the demonstration project should be on I-35 (one direction only) roughly from just north of Ames to just north of US 20.

Durable Marking Materials

The PMT engaged in discussions with area contractors through the Iowa chapter of the American Traffic Safety Services Association (ATSSA). This included a general durable marking program discussion on February 21, 2017 that was well attended by contractors and material manufacturers and suppliers.

In consideration of costs, input from adjacent state DOTs, and the contracting community in Iowa, the PMT determined that the I-35 demonstration project would include any of the following materials:

Fast Dry Modified Urethane and Polyurea as approved by either MnDOT or Illinois DOT with examples provided below:

- HPS 4
- MFUA-10
- Polyurea

Retroreflectivity Levels

The PMT did not determine acceptable retroreflectivity levels nor the penalties should the contractor not meet these levels at this time. These details are still under review and will be included in the purchasing specifications developed.

Installation Method

The Iowa DOT does not have the equipment to apply plural component (durable) pavement markings. If the demonstration is deemed a success, and the DOT can establish a long-term

contractor applied durable marking program, this would allow DOT paint crews to provide a much higher level of pavement marking guidance on the rest of the roadway network (two- and four-lane roadways). The program would also minimize disruptions to travel on the interstates (requiring much less frequency of painting), which would benefit both mobility and safety.

Draft Specification

A draft material specification was developed (Epoxy) for consideration by the PMT for the purchasing specification. Final acceptance and modifications to the draft will take place beyond the timeline of this report. The draft specification is provided below.

APPENDIX A

DRAFT Iowa DOT – Epoxy Purchasing Requirements

Epoxy Resin Pavement Markings

Scope

Provide reflectorized white and yellow two-component, 100 percent solids epoxy resin pavement markings that are free of toxic heavy metals for installation on bituminous and concrete pavement surfaces.

Requirements

A. General

Apply epoxy resin pavement markings, including lines, legends, symbols, crosswalks, and stop lines, in accordance with 2527.01—Pavement Marking Description.

Use materials capable of producing pavement markings of specified thickness as follows: For EPOXY markings, apply the epoxy pavement resin with a wet-film thickness of at least 20 mil. Apply at a greater wet-film thickness as recommended by the material manufacturer based on pavement type, environmental conditions, placement within a rumble, and other relevant factors.

Provide materials in accordance with the Retroreflectivity requirements below, unless otherwise required by the contract.

Table 2. Minimum initial retroreflectivity requirements

Minimum Coefficient of Retroreflected Luminance	
	mcd/sq.ft./ft.-cdl.
White line, symbols, and legends	300
Yellow line	200

Provide yellow markings distinguishable from white markings in the dark.

Provide epoxy resin pavement marking systems as classified by the following types:

1. Type I: A fast cure material suitable for line applications and, under ideal conditions, may not require coning.

2. Type II: A slow cure material suitable for all applications of pavement markings under controlled traffic conditions requiring coning. Provide flagging as directed by the engineer.

Use Slow Dry Type II epoxy material for epoxy pavement markings, unless otherwise required by the contract.

The department will not require the mixing of individual components before use if stored for no greater than 12 months.

B. Epoxy Resin Material

Provide epoxy resin material meeting the following requirements and characteristics:

1. Composed only of epoxy resins and pigments

2. Does not emit or leach solvents into the environment upon application to a pavement surface

3. The infrared spectrum for all components shall match the reference sample provided by the manufacturer for the product tested and approved by the department

4. Type II material completely free of Tri-Methyol Propane Tri-Acrylate and other multi-functional monomers

5. Free of lead, cadmium, mercury, hexavalent chromium, and other toxic heavy metals, as defined by the Environmental Protection Agency,

6. White material no darker than or no yellower than 17778 of Federal Standard Number 595C Colors

7. Daytime color of the yellow epoxy meeting the following CIE Chromaticity limits using illuminant “D65/2”, see Table 3.

Table 3. Daytime chromaticity coordinates

Daytime Chromaticity Coordinates (Corner Points) — Yellow				
	1	**2**	**3**	**4**
x	0.470	0.485	0.520	0.480
y	0.440	0.460	0.450	0.420

8. White daylight directional reflectance (Y) of least 83 percent,

9. Yellow daylight directional reflectance (Y) of at least 50 percent, and

10. Nighttime color of yellow meeting the following chromaticity limits in ASTM D 6628, see Table 4:

Table 4. Nighttime chromaticity coordinates

Nighttime Chromaticity Coordinates (Corner Points) — Yellow				
	1	2	3	4
x	0.575	0.508	0.473	0.510
y	0.425	0.415	0.453	0.490

B.1 Adhesion Capabilities

Provide material meeting the adhesion requirements of the American Concrete Institute Committee 403 when tested on portland cement concrete. Apply epoxy resin pavement markings during the test to concrete pavements with a tensile strength of at least 300 psi (2,070 kPa) and ensure the failure of the system occurs in the concrete during testing.

B.2 Abrasion Resistance

Provide material with an abrasion resistance wear index no greater than 82 when tested in accordance with ASTM C 501 with a CS 17 wheel under a load of 1,000 g for 1,000 cycles.

B.3 Hardness

Provide material with a Type D durometer hardness from 75 to 90 when tested in accordance with ASTM D 2240 after curing for 72 h at 73 °F ±4 °F (23 °C ±2 °C).

B.4 Tensile Strength

Provide material with a tensile strength of at least 6,000 psi (41,370 kPa) when tested in accordance with ASTM D 638 after curing for 72 h at 73 °F ±4 °F (23 °C ±2 °C).

B.5 Compressive Strength

Provide material with a compressive strength of at least 12,000 psi (82,700 kPa) when tested in accordance with ASTM D 695 after curing for 72 h at 73 °F ±4 °F (23 °C ±2 °C).

Sampling and Testing

Test the daylight directional reflectance and the color meeting the requirements of ASTM E 1349.

Provide 1 pt (0.5 L) samples of each manufacturer's lot or batch of material when manufactured to the department.

Provide 1 pt (0.5 L) samples of Part A (yellow/white epoxy resin) and Part B (catalyst) to the Materials Laboratory. Mark the samples with the following information:

1. Name of manufacturer

2. Manufacturer product number

3. Lot or batch number

4. Date of manufacture

5. Color

6. State project numbers for intended material use

Submit to the Engineer a manufacturer's Certificate of Compliance for all components of the epoxy resin pavement marking system.

Mark containers for epoxy components with the following information:

1. Name of manufacturer

2. Product identification number

3. Lot or batch number

4. Date of manufacture

5. Color

6. Net weight of contents

Construction

A. General

1. The contract documents will specify the quantity, locations, and type of pavement markings required.

2. The minimum atmospheric and surface temperatures for application of pavement markings shall follow the manufacturer's written recommendations.

3. For all pavement markings, ensure the pavement surface is dry and free from dirt, dust, oil, curing compound, and other contaminates that may interfere with markings properly bonding to the surface. Ensure the clean surface is at least one inch wider than the anticipated marking. Shoot an air blast on the pavement surface immediately prior to placing the new marking. The air blast is not intended to remove large amounts of dust, but only a very small amount of residue that might be left from the removal and cleaning operation.

4. Ensure the following for all painted and taped pavement markings:

    - Uniform thickness

    - Uniform distribution of glass beads throughout the line width

    - Line widths as specified, with a tolerance of ± 1/4 inch for 4 inch lines and ± 1/2 inch for wider lines

    - Markings have sharp edges and cutoffs at the ends

B. Traffic Control

Apply the provisions of Section 2528 to traffic control for removing and placing painted and taped pavement markings, along with the following additional requirements:

1. Place traffic control devices on the roadway before removal operations have commenced. Leave traffic control devices in place through the completed curing time of the newly applied pavement markings.

2. Do not close any longer length of lane than can be adequately removed and replace in a single working day.

3. For painted pavement markings, do not remove traffic control devices until the newly applied pavement markings are tack free.

C. Permanent Pavement Marking

1. When permanent marking is required, place:

    - Center lines, lane lines, no passing zone lines, and edge lines,

- Barrier lines and transverse lines,

- Symbols and legends, and

- Other markings required by the contract documents or by the Engineer.

2. Permanent marking will normally be required, according to this specification, for all projects on which public traffic is allowed during construction.

3. Accurately place all lines to a close tolerance using a guide extending at least three feet ahead of the machine. The location of edge lines may be referenced to the pavement edge. The locations of other longitudinal lines may be referenced to accurately locate longitudinal joints. Where such references do not exist or are not reliable, locate the lines as follows:

   a. For straight or nearly straight lines, reference the locations to a stringline set between marking line points.

   b. For curves, reference the locations to closely spaced marking line points. For sharp curves, a spacing of 10 feet may be required.

   c. Other equally effective systems the engineer approves.

D. Defective Pavement Markings.

1. Markings that are low on initial retroreflectivity up to 20 percent may, at the discretion of the engineer, be accepted with a price adjustment.

2. Repair, at no additional cost to the Contracting Authority, all pavement markings that, after application and curing, the engineer determines to be defective and not in conformance with these specifications. Remove the defective markings completely and clean to the underlying pavement surface according to the requirements of Article 2527.03, C. Remove the defective area plus all adjacent marking material extending one foot in any direction. After surface preparation work is complete, finish the repair by reapplying new marking material over the cleaned pavement surface according to the requirements of these specifications.

Glass Beads

For EPOXY linear markings, apply glass beads specified at a rate of at least 25 lb per gal. Apply beads at a greater rate if recommended by the material manufacturer to meet the required minimum levels of retroreflectivity in accordance with Table 2.

For EPOXY linear markings, apply glass beads as specified below:

Provide treated glass beads meeting the following characteristics and requirements:

1. Listed on the Approved/Qualified Products List

2. Made from clean colorless transparent glass

3. Smooth

4. Spherically shaped

5. Free from milkiness, pits, excessive air bubbles, chips, and foreign material

6. Capable of being applied by conventional striping equipment

7. Produce a retro-reflectorized line when viewed at night with automobile headlights

8. Meet the requirements of AASHTO M 247, Type 1 ―Standard Gradation‖ except with at least 80 percent true spheres

Provide beads for use with epoxy resins with a moisture resistant silicone surface treatment as recommended by the epoxy resin manufacturer.

Unless otherwise specified, provide beads packaged in moisture-proof, multi-wall shipping bags, and in containers marked with the following information:

1. Manufacturer name

2. Manufacturer address

3. Type of moisture treatment

4. Batch number

5. Date of manufacture

Deliver the containers and contents in a dry condition. The engineer will reject beads not meeting the requirements of this specification.

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