Minnesota Department of Transportation

RESEARCH SERVICES

Office of Policy Analysis, Research & Innovation

Pavement Marking Compatibility with Chip Seal and Micro Surfacing

Neal Hawkins, Principal Investigator
Center for Transportation Research and Education
Iowa State University

October 2011

Research Project
Final Report 2011-24

Your Destination...Our Priority

All agencies, departments, divisions and units that develop, use and/or purchase written materials for distribution to the public must ensure that each document contain a statement indicating that the information is available in alternative formats to individuals with disabilities upon request. Include the following statement on each document that is distributed:

To request this document in an alternative format, call Bruce Lattu at 651-366-4718 or 1-800-657-3774 (Greater Minnesota); 711 or 1-800-627-3529 (Minnesota Relay). You may also send an e-mail to bruce.lattu@state.mn.us. (Please request at least one week in advance).

Technical Report Documentation Page

1. Report No. MN/RC 2011-24	2.	3. Recipients Accession No.
4. Title and Subtitle Pavement Marking Compatibility with Chip Seal and Micro Surfacing		5. Report Date October 2011
		6.
7. Author(s) Neal Hawkins and Omar Smadi		8. Performing Organization Report No.
9. Performing Organization Name and Address Center for Transportation Research and Education Iowa State University 2711 South Loop Drive, Suite 4700 Ames, IA 50010-8664		10. Project/Task/Work Unit No.
		11. Contract (C) or Grant (G) No. (c) 89256 (wo) 7
12. Sponsoring Organization Name and Address Minnesota Department of Transportation 395 John Ireland Boulevard, Mail Stop 330 St. Paul, Minnesota 55155		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code
15. Supplementary Notes http://www.lrrb.org/pdf/201124.pdf		

16. Abstract (Limit: 250 words)

Minnesota Department of Transportation (MnDOT) staff has experienced that pavement markings do not perform well on seal coat and micro surface treated roadways, referred to as “challenging surfaces.” This report serves as a beginning point and organized approach in addressing pavement marking practices on challenging surface roadways.

The project objective was to document existing district practices and issues through several key tasks, which include a literature review, field review, and analysis of existing practice and performance. This effort identified the need for a field trial to provide control in the evaluation of these markings on challenging surfaces. An outline was developed for a future field trial effort, which will evaluate the marking performance of different combinations of pavement marking materials and installation practices.

These project findings will be used in conjunction with the resulting field trial evaluations to improve MnDOT guidance and standard practice that will result in better performance, efficiencies, and roadway safety.

17. Document Analysis/Descriptors Road markings, Retroreflectivity, Chip seals, Seal coats, Surfaces, Micro surface, Challenging surfaces		18. Availability Statement No restrictions. Document available from: National Technical Information Services, Alexandria, Virginia 22312	
19. Security Class (this report) Unclassified	20. Security Class (this page) Unclassified	21. No. of Pages 39	22. Price

Pavement Marking Compatibility with Chip Seal and Micro Surfacing

Final Report

Prepared by:

Neal Hawkins
Omar Smadi

Center for Transportation Research and Education
Iowa State University

October 2011

Published by:

Minnesota Department of Transportation
Research Services Section
395 John Ireland Boulevard, Mail Stop 330
St. Paul, Minnesota 55155-1899

Acknowledgments

The authors would like to thank the Minnesota Department of Transportation for sponsoring this research and the outstanding members of the Technical Advisory Panel for their input, dedication, and insightful feedback throughout the project. This includes:

Mitch Bartelt	MnDOT *technical liaison*
Brad Lechtenburg	MnDOT *technical liaison*
Alan Rindels	MnDOT *administrative liaison*
Lee Amundson	Lincoln County
Peter Buchen	MnDOT
Bruce Daniel	MnDOT
Dave Gustafson	MnDOT
Kenneth Johnson	MnDOT
Patty Johnson	MnDOT
Sheila Johnson	MnDOT
Chris Kufner	MnDOT
Derek Leuer	MnDOT
Wayne Lindblom	MnDOT
Jim McGraw	MnDOT
Randy Newton	City of Eden Prairie
Tom Peters	MnDOT
Ted Ulven	MnDOT

Table of Contents

List of Figures

List of Tables

Executive Summary

Minnesota Department of Transportation (MnDOT) staff has experienced that pavement markings do not perform well on non-smooth roadway surfaces such as seal coat and micro surface treated roadways otherwise referred to as challenging surfaces This report serves as a beginning point and organized approach in addressing pavement marking practices on challenging surface roadways.

The project objective was to document existing district practices and issues through several key tasks which include a literature review, field review, and analysis of existing practice and performance. A summary of findings on this includes:

- Marking performance on challenging surfaces is an on-going problematic issue
- District staff are experimenting with variety of materials (latex, all weather paint, high build, epoxy) and installation practices with little success over the first year with any product
- Staff have a strong desire to standardize pavement marking installation practices on these surfaces through using standard materials and methods, and are seeking solutions to improving effectiveness.

The end result, and overall feeling of the project Technical Advisory Panel, was that a field trial is needed to provide control in the evaluation of these markings on challenging surfaces. An outline was developed for a future field trial effort, which will evaluate the marking performance of different combinations of pavement marking materials and installation practices. These project findings will be used in conjunction with the future field trial evaluation to:

- Improve MnDOT guidance, support, and standard practices for both central striping and the districts
- Increase efficiency for both construction and maintenance activities, and
- Improve both the day and nighttime performance and durability for pavement markings on challenging surfaces, which will result in improved public safety.

The results from this research are expected to benefit both MnDOT and any agency trying to improve pavement marking performance on seal coat or micro-surfaced roadways.

Chapter 1
Introduction

High quality well maintained pavement markings are an essential component towards roadway safety. The Minnesota Department of Transportation (MnDOT) staff initiated this effort to address concerns that pavement markings do not perform well on certain roadway surfaces, such as seal coat and micro surface treatments, otherwise referred to as challenging surfaces within this report.

This effort is a beginning point for MnDOT towards an organized approach in addressing pavement marking practices on challenging surfaces. This was accomplished in four tasks as summarized below and included within Chapter 2 of this report.

Task 1 (Literature Review). This task summarizes the project need, defines roadway surface treatment types, and presents the literature review findings from published and un-published sources. This section also includes the results from a survey of other state DOT pavement marking practices on challenging surfaces

Task 2 (Field Review). This task summarizes the technical guidance currently provided by MnDOT for pavement markings on challenging surfaces, summarizes current specifications for these types of surfaces, includes a MnDOT agency survey and follow-up phone discussions covering markings on challenging surfaces, and includes data and observational information from a District 3B field visit.

Task 3 (Analysis). This task provides an analysis of current MnDOT practices, based upon findings from Tasks 1 & 2, identifies key problematic issues along with potential solutions and strategies to address pavement marking performance on challenging surfaces.

Task 4 (Outline for Field Trial). This task provides the developed outline for a future field trial. The field trial will evaluate the marking performance for different combinations of pavement marking materials and installation practices on challenging surfaces. The trial is described in terms of potential materials, roadway characteristics, application options, test deck layout, and test deck evaluation.

Chapter 2
Tasks

Task 1 – Literature Review

Background

This section summarizes the project need, defines roadway surface treatment types, and presents the findings from Task 1 (Literature Review). Minnesota Department of Transportation (MnDOT) staff reported that pavement markings do not perform well on non-smooth roadway surfaces such as seal coat and micro surface treatments (otherwise referred to as challenging surfaces). Figure 1 illustrates the typical performance of markings on these types of surfaces. The lack of performance can be attributed to a number of factors including:

1. Seal coat and micro surface treatments by design experience a certain degree of rock loss which also removes the pavement marking material.
2. These course surface conditions have an impact on the ability to place the marking at a sufficient (mill) thickness which in turn impacts performance and bead placement.
3. The asphalt emulsions used and curing times.

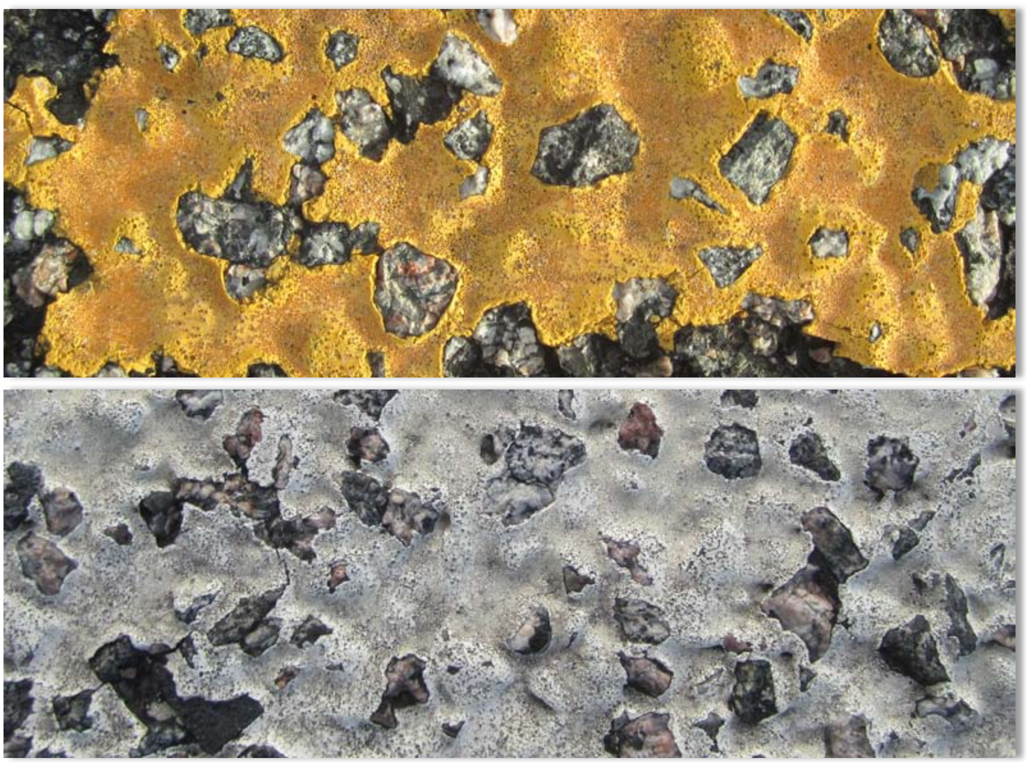

Figure 1. Typical Marking Damage on a Seal Coat Surface

Description of Challenging Surfaces

For the purposes of this report, MnDOT challenging conditions will refer to the following surface treatments:

Seal Coat – The Minnesota Seal Coat Handbook (1) describes seal coat treatments as follows: "Seal coating is a common preventive maintenance activity in Minnesota performed by most cities, counties and rural MnDOT districts. It involves spraying asphalt cement on the surface of an existing pavement followed by the application of a cover aggregate. The asphalt cement is usually emulsified (suspended in water) to allow for it to be applied without the addition of extreme heat. The cover aggregate is normally either naturally occurring gravel or crushed aggregate such as granite, quartzite or trap rock (basalt)". Seal coats include a bituminous material meeting the specifications of MnDOT special provision 2356 and an aggregate which complies with MnDOT gradation and quality standards (2). Figure 2 shows a typical MnDOT seal coat surface treatment and application information.

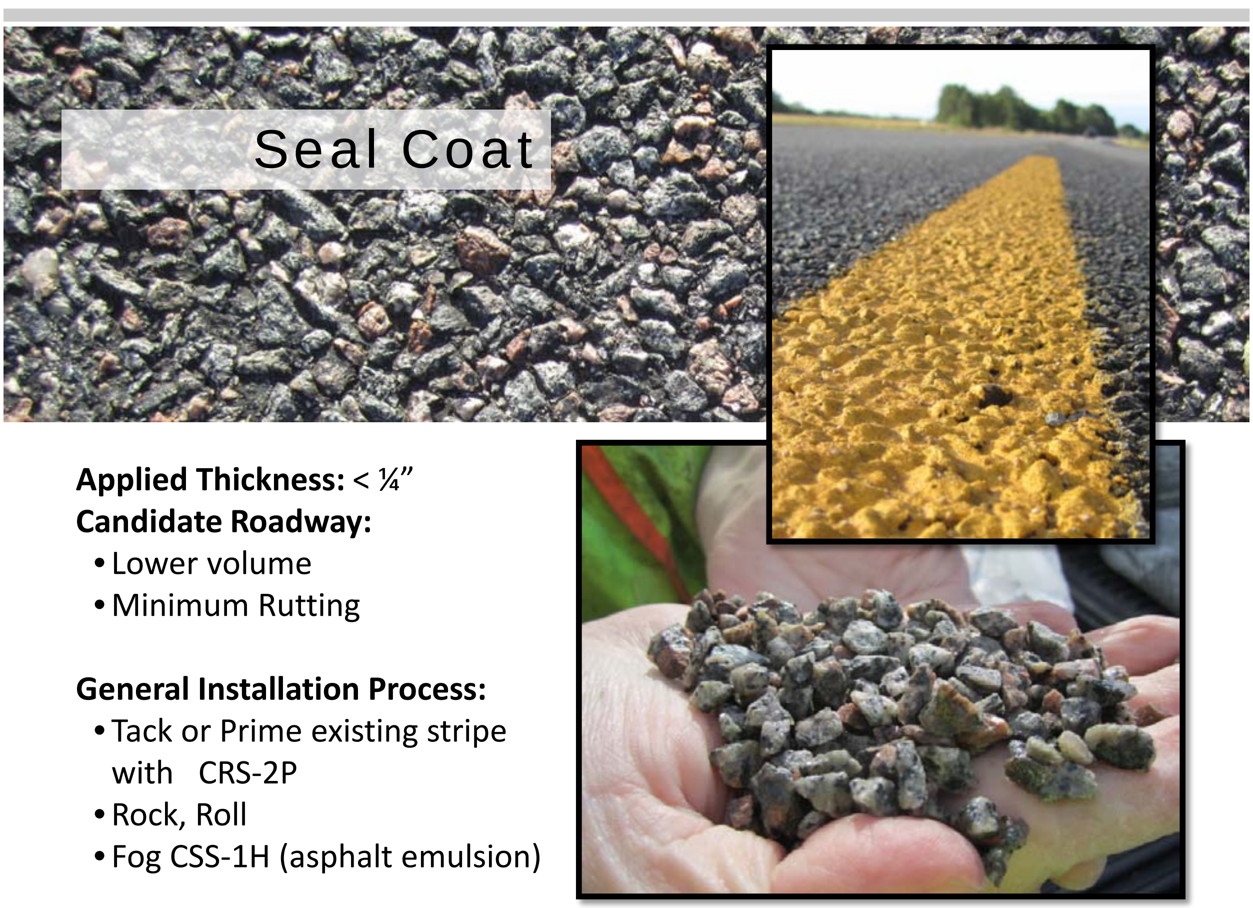

Figure 2. Typical Seal Coat Surface Treatment

Micro Surface – The LRRB report on Preventive Maintenance Best Practices report (3) describes micro surface treatments as follows: "Micro-surface treatments can be defined as a mixture of fine aggregate, asphalt emulsion and mineral filler such as Portland cement; this treatment uses a chemically controlled curing process which typically allows traffic to use the roadway within one hour, as opposed to slurry seals which use a thermally controlled curing process. Furthermore the additional mix stability, resulting from the latexes, makes this treatment ideal for higher volume roads, where a chip seal would be impractical. This treatment is applied as in slurry form and placed by a slurry box that uses a screed to control the surface elevation. A micro-surface can be applied in relatively thick layers, which makes it ideal for filling in ruts, and correcting other deformations. The main disadvantage of this treatment when compared to a seal coat or other surface treatments is its relatively high unit cost. Micro-surfacing also can be used to restore friction to an otherwise sound pavement surface." Figure 3 shows a typical MnDOT seal coat surface treatment and application information.

Figure 3. Typical Micro Surface Treatment

Published Literature

The performance of pavement markings on challenging surfaces is not well documented within the literature. One study, from 2003, for the Texas DOT (4) which focused on thermoplastic markings provides some insight on the problems faced when placing markings on seal coat surfaces.

A survey of TxDOT districts found the following observed pavement marking problem areas when placed on new seal coat roadways:

- rapid deterioration of retroreflectivity for thermoplastic,
- paint often does not last a full year when placed on a new sealcoat,
- unable to cover the entire aggregate surface with thermoplastic sprayed at standard thickness,
- thermoplastic on tops of the aggregates wears quickly,
- asphalt bleeds to surface and tracked onto new markings,
- aggregates “pop out” of the new sealcoat surface and remove the marking material,

Maintaining initial and long-term retroreflectivity on seal coat roadways was reported to be a major challenge for TxDOT with the primary issues being influenced by certain attributes of the seal coat surface itself, including:

- aggregate size,
- surface voids,
- surface texture, and
- length of sealcoat curing time prior to striping.

The study conducted a number of relevant in-service evaluations, as follows:

Evaluation #1 Effect of surface texture on initial retroreflectivity:

> **Are the rough-textured surface characteristics of new seal coat roadways detrimental to initial pavement marking retroreflectivity when compared to Hot Mix Asphalt Cement (HMAC) smooth surfaces?**
>
> Findings: **Yes**, although based on a small sample size, after 14 days the smooth surface had higher levels of retroreflectivity than the seal coat surface (using the same marking materials), see Figure 4. The evaluation also found that the markings placed on the HMAC surface had greater uniformity in retroreflectivity readings.

Figure 4. Thermoplastic Marking on Seal Coat (left) vs. HMAC (right) (4)

Evaluation #2 Effect of surface texture on retroreflectivity over time:

Are the rough-textured surface characteristics of new seal coat roadways detrimental to pavement marking retroreflectivity over time when compared to HMAC (smooth) surfaces?

Findings: **Yes**, both initially and after eight months, the smooth surface had higher levels of retroreflectivity than the seal coat surface, see Figure 5. The evaluation also found that after eight months the retroreflectivity levels for the markings on seal coat surfaces had degraded by 36 to 55 percent of initial levels while in contrast the HMAC thermoplastic markings had lost only 0 to 7 percent of their initial values. Another finding showed that the difference in directional retroreflectivity for yellow centerline markings were significantly less on HMAC versus seal coat surfaces which indicated a better binder/bead coverage for markings on HMAC surfaces and again the HMAC markings had better uniformity in retroreflectivity readings.

Figure 5. Thermoplastic after Two Years (Seal Coat on Left vs. HMAC on Right) (4)

Evaluation #3 Determine optimum thermoplastic thickness on new seal coat:

Would increasing the thickness of the thermoplastic marking on seal coat roadways improve retroreflectivity (initial or long term)?

Findings: **No initially, Yes long term.** Thickness was found to have very little effect on initial retroreflectivity; however, it had a significant effect on long-term retroreflectivity. Markings with a thickness equal to or greater than 90 mil retained initial levels of retroreflectivity significantly better over time in contrast to those thinner than 90 mil. For yellow centerline markings, the difference in directional retroreflectivity was less pronounced at greater marking thicknesses.

Evaluation #4 Evaluate various paint and thermoplastic applications on new seal coat:

How does the waterborne HD-21 (25 mil) perform on new seal coat surfaces?

Findings: **Mixed results.** The white paint maintained reasonable levels of retroreflectivity after four months, averaging 170 – 230 mcd/m^2/lx (mcd). However, all of the yellow sections were below 100 mcd. In contrast, all of the thermoplastic markings (at 100 mils thick) displayed adequate retroreflectivity after four months, averaging 200 to 400 mcd for white and 150 to 225 mcd for yellow.

Would using paint (waterborne HD-21 at 25 mil) as a primer on a new seal coat lead to better thermoplastic performance (by filling the voids)?

Findings: **Not significantly.** The thermoplastic applied over a paint primer maintained slightly higher levels of retroreflectivity versus unprimed both initially and after four months, however these findings were not statistically significant.

Evaluation #5 Evaluate the effect of seal coat aggregate size on marking performance:

How does the retroreflective performance of a 100 mil thermoplastic differ when placed on a Grade 3 (larger aggregate) versus Grade 4 (smaller aggregate) seal coat surface?

Findings: **Worse.** The Grade 4 (smaller aggregate) seal coat provided significantly higher levels of thermoplastic retroreflectivity versus the Grade 3 (larger aggregate) seal coat. The average white edge line retroreflectivity was 55 mcd higher and the average yellow centerline was 70 mcd higher for the Grade 4 seal coat.

Service Life Evaluation:

What are reasonable expectations for thermoplastic service life as a function of pavement surface and marking color?

Findings: Based on an end-of-service life retroreflectivity threshold of 100 mcd and a maximum service life of four years, average thermoplastic service lives for new pavement surfaces were estimated as follows:

- HMAC 4.0 years (white), 3.9 years (yellow)
- Seal Coat: 3.2 years (white), 2.9 years (yellow)

Summary of Literature Findings:

Applicable findings towards MnDOT's interests show that seal coat surfaces present a number of additional striping and performance challenges when compared to HMAC or smooth surfaces. In summary, markings placed on challenging surfaces as compared to smooth surfaces (HMAC) have been documented to show the following:

- Worse uniformity and retroreflectivity
- Faster degradation of retroreflectivity
- Higher differences in directional retroreflectivity of yellow centerline markings.
- Require higher levels of marking thickness
- Marking performance is sensitive to material thickness and aggregate size
- Overall reduced service life of up to one-year.

Other State DOT Practices on Challenging Surfaces

The research team conducted phone interviews with a number of Midwestern state DOT's to assess their current practices when placing pavement markings on challenging surfaces. A summary of responses follows.

Missouri DOT

- Chip seal is the predominant maintenance activity on low volume roads.
- Process includes:
    - Prior to chip seal do the tabs (Type 1 temporary raised pavement markings)

- o Then oil, rock, roll, sweep, broom, then take shields off the tabs.
  - o Wait two weeks and apply waterborne paint (feel the longer they wait the better performance they get).
  - o The majority of crews (not policy) but perhaps a best practice is to go in and within a week put down a thin stripe (10-12 mil) of paint to have something down. Then come back a month later to stripe properly with 15mil application (buys them more than just the two weeks).
- Maintenance forces do not like to maintain the tabs.
- Haven't monitored life of stripe on chip seal (typically low volume roads) definitely get one year and in some cases two years.
- They do not use very much micro-surfacing. Have in their spec book guidance on micro-surfacing saying that contractor had to wait 14 days before striping.

Nebraska DOR

- For challenging surfaces, they paint with maintenance crew using waterborne (latex). There is no set wait time to paint, this is set by crews schedule (typically within 2 weeks) but there is no policy on this.
- Treated surfaces are not tracked for marking purposes. Not sure on quantity but feels maintenance forces do quite a bit of these surfaces. No durables for this type of surface.

Illinois DOT

- They have few challenging surfaces. Isolated seal coat sections but not on widespread basis. They have tried different things:
- Wait two weeks broom then stripe (ok and most effective but tightens down on time restrictions where have little or no markings on road). Would only use paint in this instance as no luck with durables.
- Come back with paint next time (painted on annual basis). Never get presence and retro measurements versus on hot mix.
- On slurry seals, have used extruded thermo and that seems to do OK. Use quite a bit of thermo (has been reduced over last few years).

South Dakota DOT

- Waterborne paint (initial) which lasts about one year.
- Only do chip seal. No special pre-treatment. Dealt with as regular asphalt surface which is painted annually. Chip seal normally rougher so plows take top part off and have observed that these are worn off when painted annually.

Iowa DOT

- Only use waterborne paint on seal coat surfaces.
- No special treatments.
- Challenging surfaces make up less than 5 percent of the 10,000 mile network.

Louisiana DOTD

The DOTD has been working internally towards a policy on pavement markings on challenging surfaces. Depending on the district some use 40 mil thermo with type 3 bead, some use latex. They have not had good success (low retro) and have questioned if they were placing enough thermoplastic material to hold type 3 bead. A small field test was conducted to evaluate thermoplastic marking material (extruded and sprayed at different thicknesses) utilizing different bead packages and application rates (standard M247, Type 3, and 1.9 refraction index). Table 1 shows the results of this experiment over a 28 month evaluation period (5). As shown, the 90 mil extruded thermo with standard single drop is the best performing product after 28 months.

Table 1. Louisiana DOTD Thermoplastic Evaluation

LA 43 1.9 BEAD TEST								
On Seal Coat		8/14/2008	10/2/2008	11/25/08	02/17/09	07/23/09	3/18/2010	1/27/2011
Color	TYPE	Initial	Initial	3 Month	6 Month	9 Month	18 months	28 months
White	90 MIL STANDARD SINGLE DROP		395	403	436	474	500	266
Yellow	90 MIL STANDARD DOUBLE DROP		227	241	259	295	274	139
White	90 MIL STANDARD DOUBLE DROP		402	378	376	470	424	255
White	90 MIL 1.9 BEAD		660	663	641	670	750	216
Yellow	90 MIL 1.9 BEAD		347	246	187	340	371	169
White	90MIL 1.9 BEAD		855	868	896	938	948	245
White	40 MIL TYPE 3 BEAD	271		176	162	165	167	192
Yellow	40 MIL TYPE 3 BEAD	137		121	129	137	100	102
White	40 MIL TYPE 3 BEAD	232		117	111	125	133	185
White	40 MIL 1.9 BEAD 10 # 100 SQ FT.	1783		901	947	798	598	183
Yellow	40 MIL 1.9 BEAD 10 # 100 SQ FT.	275		212	184	192	120	71
White	40 MIL 1.9 BEAD 10 # 100 SQ FT.	1400		802	730	760	568	202
White	40 MIL 1.9 BEAD 10 # 100 SQ FT.	1261		446	446	432	329	254
White	40 MIL 1.9 BEAD 10 # 100 SQ FT.	1239		487	518	409	310	170
Yellow	40 MIL 1.9 BEAD 15 # 100 SQ FT.	328		220	207	211	150	100

ATSSA Pavement Marking Committee Questionnaire – December 2010

In a recent questionnaire sent out by the American Traffic Safety Services Association (ATSSA) several state DOT's identified issues related to pavement marking performance on challenging surfaces. These included the states of Minnesota, Louisiana, Massachusetts, South Dakota, and South Carolina. The questionnaire results are available on the ATSSA web site (for members only) which can be found at the following: http://www.atssa.com/cs/pavement-marking-committee.

Task 2 – Field Review

MnDOT provides a number of key reference documents for both pavement marking material selection on challenging surfaces and the placement of these paving materials. This section summarizes these key documents.

Technical Memorandum for Pavement Marking Selection

MnDOT provides material selection guidance to each district through a technical memorandum (6), as shown in Figure 6. New seal coat and micro surface roadways are considered as having a remaining service life of more than 2 years therefore would receive either paint or epoxy markings based on ADT.

MINNESOTA DEPARTMENT OF TRANSPORTATION, Engineering Services Division,

Technical Memorandum No. 08-10-T-02, May 20, 2008

TWO LANE TWO WAY HIGHWAYS

Remaining Pavement Surface Life[1] (years)	ADT			
	<1,500		>1,500	
	Edgeline	Centerline	Edgeline	Centerline
0-2	Paint	Paint	Paint	Paint
2+	Paint	Paint	Epoxy	Epoxy

[1] Anticipated life of existing pavement is based on planned projects and anticipated life of surface is based on preventive maintenance plans. For the purpose of this tech memo the expected life of a seal coat is greater than 6 years. All marking materials used shall be on MnDOT's Qualified Products list.

Figure 6. MnDOT Technical Memorandum

MnDOT Standard Specifications for Seal Coat and Micro-surfacing

MnDOT provides guidance on the placement of challenging condition treatments through both handbook references and actual specifications. A summary of reference information follows:

- Minnesota Seal Coat Handbook (1), see Figure 7
- MnDOT specification 3127 Fine Aggregate for Bituminous Seal Coat
- MnDOT specification 2356 Bituminous Fog Seal
- MnDOT specification 2355 Bituminous Seal Coat

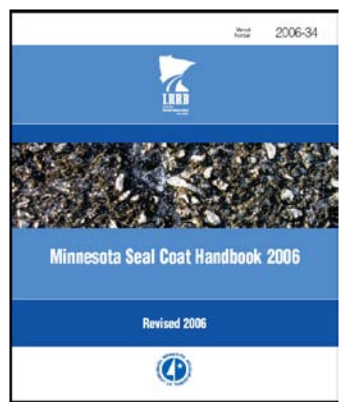

Figure 7. Minnesota Seal Coat Handbook

Agency Survey (Email)

The research team sent out an email survey to selected MnDOT staff to document existing practices and experiences specific to pavement markings on challenging surface roadways. This information follows:

Email Survey Results Question #1. What has been your experience regarding installing/maintaining pavement markings on challenging surface roadways?

District 3B (St. Cloud)

- Have about 3 years experience with this.
- We tack the stripes with CRS2P when doing seal coats and tack the whole roadway with CSS1H when doing micro-surfacing. The plows wear them off.
- Try to wait two weeks on seal coats and 4-5 weeks on micro-surfacing.
- We don't use epoxy the same year, wait until the road needs striping again and then apply.

District 7 (Mankato)

- Maintenance chip seals and sand seals, latex the first year, then epoxy the next year. The latex has degraded enough to give the epoxy a better chance to adhere.
- Inlaid tape, we are going to groove all surfaces on new construction. This also gives the "spotter" a better chance to make field decisions without the roller on his tail.
- We use epoxy on all new construction, even if the tech memo would allow latex.
- There is need for either a better specification, method or product for interim markings. (Ultra-violet sensitive product that bio-degrades in a week, water soluble corn based paint that washes away after two or so rains). These products really do not need to be reflective, if you've seen short latex lines on a chip seal, the beads are ineffective.

District 2 (Crookston)

- Typically the seal coated sections of highway last seven years. Some even longer before being overlaid.
- The only special treatment would be the overlap of the aggregate material at the centerline of the highway. During the last five years we have added a double layer overlap of the fog seal material at the centerline hoping to seal the area better against wear from the snowplows and provide a darker background contrast to the centerline markings. The centerline markings are replaced after both the seal coat (aggregate) and fog seal operations using a latex interim striping (smaller in dimension than the permanent regular marking).
- Repeatedly noticed the loss of the aggregate material the first and sometimes even the second year of winter maintenance. Also there appears to be a problem with reflectivity even when the paint is good because of the beads filling in the low areas around the aggregate where the full light of the headlights does not reach them.
- Suggest permanently replacing pavement markings with latex for the first two years of the seal coat life.

Email Survey Results Question #2. If you just finished a new seal coat or micro surfaced roadway, what would be the process in terms of installing the pavement markings?

District 3B (St. Cloud)

- Seal coat - temporary centerline striping followed up with high build latex with wet reflective elements in about two weeks.
- Micro-surfacing - temporary centerline and edge stripes followed up with high-build latex with wet reflective elements in 4-5 weeks.
- Epoxy will be placed the next time the roadway needs striping.

District 7 (Mankato)

- In the past when we used latex on construction projects, chip seals with a fog seal afterward, we did two applications of latex about two weeks apart.

District 2 (Crookston)

- After both the seal coat and fog seal operations are completed the interim latex centerline and turn bar markings are placed. The interim markings are smaller in dimension (smaller in dimension than the permanent regular marking).

- There is a seventy-two hour curing period that the fog seal must achieve before placing the epoxy permanent markings to the road surface along with the belief that the epoxy bond to the road surface is only as strong as the latex bond to the surface under the epoxy paint.

Agency Survey (Phone Interviews)

The research team called a number of MnDOT staff to document existing pavement marking practices and experiences specific to pavement markings on challenging surfaces. This information follows:

District 1B (Virginia)

- For seal coat roads we have done high build latex but the traffic engineer decided that this didn't work. Believe just regular latex did not even get them through the winter.
- For seal coat, we wait to paint a minimum of 10 days after fog seal, and have roughly 7 different highways using this method.
- Traffic engineer wanted to go back to epoxy on roads with volume (where called for).
- Not sure if epoxy last as long on chip seal as on smooth roads.
- For material selection, follow tech memo (epoxy, paint) high build with elements didn’t compare to epoxy.
- Have not used tape or other products on seal coat.
- Just use a primer coat over old markings.
- Haven’t tried micro surfacing.

District 1 Maintenance

- Have not had that many chip seals. Had one that included epoxy as final marking on chip seal and next year had to come back and stripe with epoxy again. Did same thing with HB latex and next year came back and restriped with epoxy.
- Really more of the presence that drives the restripe decision.
- Have put epoxy on a couple of these and let ride at least 2 years.
- Apply year 1 latex, year 2 epoxy, then watch and see.
- Feel they get a minimum of 3 years from epoxy depending on traffic and snow but see a definite reduction in terms of performance of epoxy on seal coat (has to do with fact that chip seal putting down on aggregate surface and these pop out).
- Inclined to use epoxy to get over the winter. Not sure what to do the interim skip line in terms of materials e.g. latex then epoxy.

District 4 (Detroit Lakes)

- Interim marking for centerline with latex, wait 14 days then stripe everything with latex.
- The next year use epoxy (over the latex). If they put the epoxy initially, it wouldn’t last any longer than the latex. No special treatment just paint epoxy over latex.
- Feels that the epoxy gives about 3 years when placed over the initial latex.
- Problem with seal coat is that the fog sealant bleeds through the paint.
- Expect poor performance no matter what is installed the first year.
- Tape is an issue because of the need to cover it or grind it off.
- They do quite a few lower volume roads with latex each year.

Figure 8 shows various retroreflectivity readings for roadways that have seal coats within District 4. According to the data, these were all roadways that were seal coated in 2010, and also marked with latex in 2010. As shown, some of these readings are very bad, while the readings on US 59 and TH 87 are surprisingly good. Some of the poor readings on TH 32 can be explained by turning truck traffic in the area for a construction project. The first two rows display the difference in retroreflectivity readings due to directionality (difference of 63 mcd) which is similar to what has been documented in the literature.

9/8/2010	D4	MN34-I	043+00.700	065+00.000	CL	LATEX	2010	143	55	Seal Coat
9/8/2010	D4	MN34-D	065+00.000	044+00.000	CL	LATEX	2010	80	55	Seal Coat
9/8/2010	D4	MN87-D	027+00.000	003+00.000	CL	LATEX	2010	118	55	Seal Coat
9/8/2010	D4	MN32-I	000+00.000	015+00.000	CL	LATEX	2010	112	55	Seal Coat
9/21/2010	D4	MN34-I	043+00.700	064+00.800	REL	LATEX	2010	227	55	Seal Coat
9/21/2010	D4	MN34-D	064+00.800	043+00.700	REL	LATEX	2010	221	55	Seal Coat
9/21/2010	D4	US59-D	238+00.000	224+00.400	REL	LATEX	2010	236	55	Seal Coat
9/21/2010	D4	US59-I	224+00.400	239+00.400	REL	LATEX	2010	230	55	Seal Coat
9/21/2010	D4	MN32-I	000+00.000	015+00.000	REL	LATEX	2010	249	55	Seal Coat
9/21/2010	D4	MN32-D	015+00.000	000+00.000	REL	LATEX	2010	253	55	Seal Coat
9/22/2010	D4	MN87-I	003+00.000	029+00.300	REL	LATEX	2010	218	55	Seal Coat
9/22/2010	D4	MN87-D	029+00.300	003+00.000	REL	LATEX	2010	219	55	Seal Coat

Figure 8. District 4 Retroreflectivity Readings for Latex on Seal Coat

Metro District

Micro-surfacing:

- This surface does not hold striping at all especially first year… takes about 2 yrs. This is a challenge as latex is thin and epoxy is so hard that it fractures off.
- Do scratch course across whole road (20lb/yd^2) then come back through with wear course at 15 lb/yd^2 but this is not placed where stripe goes in order to protect the stripe.
- Could groove in but costly.
- Run right out to fog line (edge) which goes on outside. This creates a small pocket of water but hasn't been an issue. Save 85-90% of stripe versus loosing this the first year.
- Typically will use epoxy (Year 1) in above situation with wet retroreflective elements.

Seal Coat:

- Stripe is placed on the crown of the road and plowing with underbody blade will peel off both paint and seal coat.
- Still trying different paint products with this and would like to use high-build with elements. In metro should use epoxy (based on traffic) but want to switch to high-build. There are several challenges in that the tech memo specifies tape or epoxy on challenging surfaces but this doesn't work.
- They have tested both epoxy and latex and neither do very good over the first year.
- They do not do much seal coat in the metro.

Field Visit

This section summarizes findings from a MnDOT field review which included both a project and district level review with staff. The purpose of the review was to document current practices in terms of issues related to pavement markings on challenging surfaces both initially and long-term. The field visit was conducted in September of 2010 and coincided with the placement of permanent pavement markings within District 3B (St. Cloud).

I-94 Project

The section of I-94, shown in Figure 9, was micro surfaced in June of 2010 at which time a temporary pavement marking was applied using a 10 mil latex application (White edge line R_L=120 mcd after two months). This 4-lane divided section of I-94 carries roughly 27,000 vehicles per day and the existing surface was roughly 5 years old and experiencing some raveling and pot holes. MnDOT chose to install the micro surface to extend the years of service by seven to ten years.

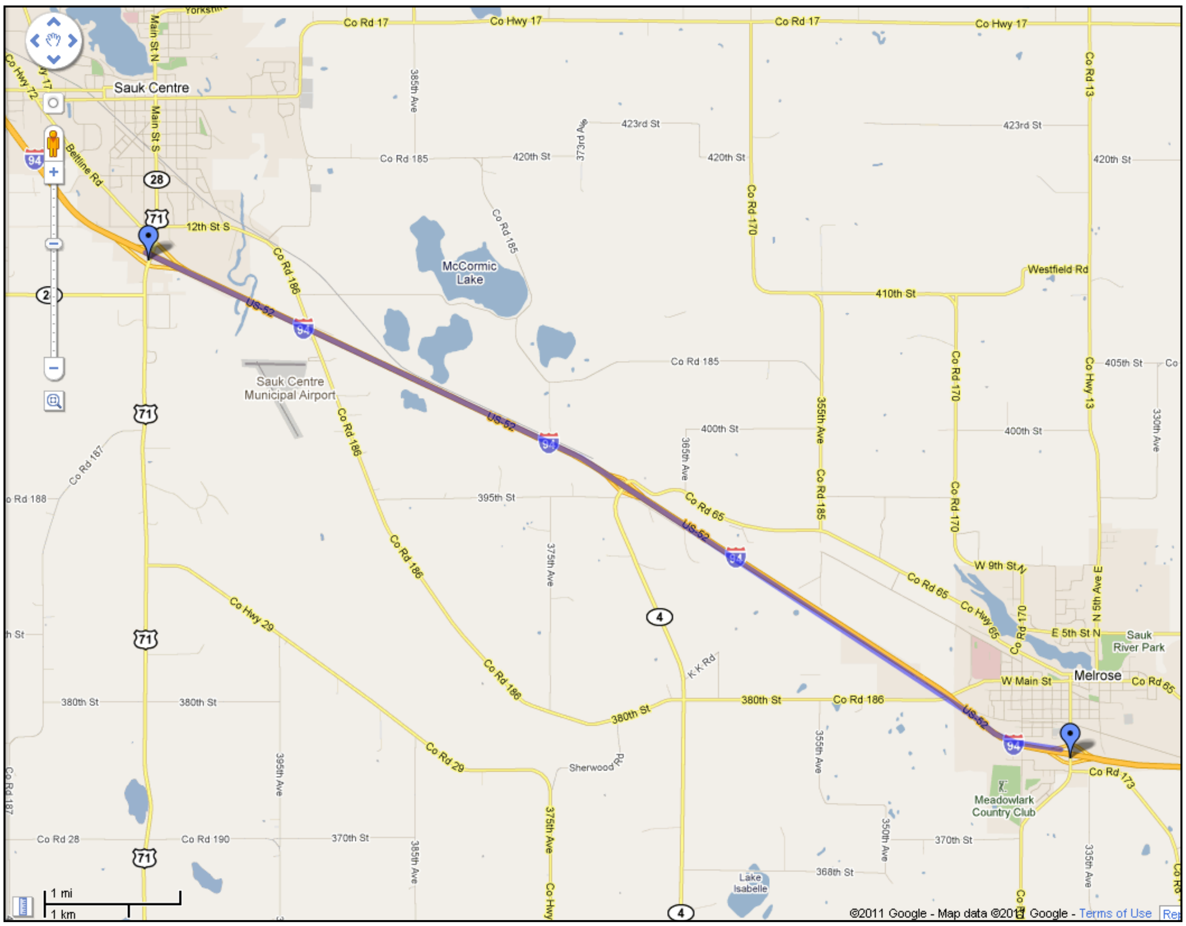

Figure 9. I-94 Micro Surface Project Limits (2010)

The permanent pavement markings were placed in September of 2010. As shown in Figure 10, these new 4" wide markings were offset from the temporary markings by approximately 2 inches (edge lines only) to observe differences in wear over time and to consider the difference in adhesion of the permanent marking when placed over a primer coating (the temporary marking) versus over the micro surface alone.

Figure 10. I-94 Micro Surface Project and Edge Line Marking Placement

Figure 11 shows the installation of the permanent marking materials which includes 25 mil of high build waterborne paint (3M/Ennis) and a double drop of beads (3M wet retroreflective elements and Type 1 beads). This product combination is referred to by staff as All Weather Paint (AWP). The new markings were installed at an application speed of approximately 7.5 mph, the weather was dry, sunny, 65 degrees, and the white markings measured an initial retroreflectivity of 420 mcd.

Additional retroreflectivity measurements taken in October (one-month after installation) are shown in Figure 12 below:

Figure 11. I-94 Micro Surface Project Permanent Marking Placement

Location		Roadway		Pavement Marking		Retroreflectivity (mcd)	
Highway	**Ref. Pt.**	**Surface**	**Year**	**Striping**	**Year**	**Left Edge (Yellow)**	**Right Edge (White)**
94	131 Ramp	Microsurface	2010	All Weather	2010	272	324
	132	Microsurface	2010	All Weather	2010		368
	133.95	Microsurface	2010	All Weather	2010	299	
	134.04	Microsurface	2010	All Weather	2010	398	434

Figure 12. I-94 Pavement Marking Performance

Other District 3B Locations

The field visit also covered a review of other pavement markings on challenging surfaces within MnDOT District 3B. The combination of products and surfaces varies slightly as noted below and performance is noted in terms of retroreflectivity (mcd) as measured in 2010. All centerline markings are yellow and all edge line markings are white unless otherwise noted:

Highway 25

Figure 13 shows several roadway images and selective 2010 retroreflectivity readings. In 2009, these sections of roadway had an ADT of 3,400 vehicles per day. A brief discussion on documented pavement marking performance by reference point (@ RP#) follows:

@ 81.999 AWP performance after one summer: Acceptable but not overwhelming for left edge line (192 mcd) and centerline (152 mcd) which is worse than the epoxy marking after one-year from reference point 82.868. The right edge line (320 mcd) had much better retroreflectivity but shows the inconsistency which can occur given the seal coat surface or if both lines were measured in the same direction.

@ 82.868 This one-mile test section has two stripes for each edge line with the inside line (closest to centerline) being epoxy, which was installed with the seal coat in 2009, and the outside edge line being AWP, which was installed in 2010. After one year of service, the epoxy edge lines are performing well (320/301 mcd). The "over the summer" readings for AWP edge lines are excellent as well (348/420 mcd). However, the new AWP center line markings measured only 26 mcd higher than the one-year old epoxy center line.

@ 93.000 AWP performance after one summer: Acceptable but still a big variation between edge line markings.

Location		Roadway		Pavement Marking		Retroreflectivity (mcd)		
Highway	**Ref. Pt.**	**Surface**	**Year**	**Striping**	**Year**	**Left Edge**	**Center**	**Right Edge**
25	81.999	Seal Coat	2010	All Weather	2010	192	152	320
	82.868	Seal Coat	2009	Epoxy	2009	320	164	301
	82.868	Seal Coat	2009	All Weather	2010	348	190	420
	93	Seal Coat	2010	All Weather	2010	354	163	186

Hwy 25 @ Reference Point 81.993

Hwy 25 @ Reference Point 93.020

Figure 13. Highway 25 Pavement Marking Performance

Highway 47

Figure 14 shows several roadway images and selective 2010 retroreflectivity readings. In 2009, these sections of roadway had an ADT of 1,400 vehicles per day. A brief discussion on documented pavement marking performance by reference point (@ RP#) follows:

@ 60.000 AWP performance after one year: Given the lower volume, the AWP performed adequately over the winter. The large difference between edge line readings (left at 112 and right at 473 mcd) has been explained by noting that the right edge line markings are on smooth pavement where the left edge line marking is on a seal coat surface.

@ 67.000 AWP performance after one year: Very similar performance to what was found at reference point 60. The yellow center line marking did not perform well (87 mcd) over the one year period.

Location		Roadway		Pavement Marking		Retroreflectivity (mcd)		
Highway	**Ref. Pt.**	**Surface**	**Year**	**Striping**	**Year**	**Left Edge**	**Center**	**Right Edge**
47	60	Seal Coat	2009	All Weather	2009	112	135	473
	67	Seal Coat	2009	All Weather	2009	133	87	325

Hwy 47 @ Reference Point 60

Hwy 47 @ Reference Point 67

Figure 14. Highway 47 Pavement Marking Performance

Highway 71

Figure 15 shows several roadway images and selective 2010 retroreflectivity readings. In 2009, these sections of roadway had an ADT of 3,350 vehicles per day. A brief discussion on documented pavement marking performance by reference point (@ RP#) follows:

@ 169.99 This section provides a comparison where AWP was used initially over a seal coat in 2008. After one year, all but one segment was repainted using epoxy. Staff felt, from a night time driving perspective, that they were able to get 2 years out of the AWP segment, however, the right edge line measured 59 mcd only. The one year old epoxy performance was marginal (105/116 mcd), however, it might not perform over another winter.

@ 172.00 This section shows much better performance for the epoxy after one year compared to the previous segment when looking at the right edge line. The performance of the left edge line is marginal.

@ 174.00 Same results as at reference post 172.00, good performance over the one year period for the right edge line and marginal for the left edge line.

Location		Roadway		Pavement Marking		Retroreflectivity (mcd)		
Highway	**Ref. Pt.**	**Surface**	**Year**	**Striping**	**Year**	**Left Edge**	**Center**	**Right Edge**
71	169.99	Seal Coat	2008	All Weather	2008			59
	169.99	Seal Coat	2008	Epoxy	2009		105	116
	172	Seal Coat	2008	Epoxy	2009	163	127	223
	174	Seal Coat	2008	Epoxy	2009	130	125	263


Hwy 71 @ Reference Point 169.958


Hwy 71 @ Reference Point 173.998

Figure 15. Highway 71 Pavement Marking Performance

Highway 65

Figure 16 shows several roadway images and selective 2010 retroreflectivity readings for Highway 65. In 2009, this section of road had an ADT of 9,500 vehicles per day. A brief discussion on documented pavement marking performance by reference point (@ RP#) follows:

@ 47.00 Given the higher traffic volumes the AWP, which was initially applied, has performed well over the one year period where the left edge line measured 244 mcd.

Highway 4

Figure 16 also shows several roadway images and selective 2010 retroreflectivity readings for Highway 4. In 2009, this section of road had an ADT of 1,800 vehicles per day. A brief discussion on documented pavement marking performance by reference point (@ RP#) follows:

@ 163.00 Latex paint was applied and at the end of the summer and is still providing excellent retroreflectivity. This emphasizes the impact of traffic on both durability and retroreflectivity.

Location		Roadway		Pavement Marking		Retroreflectivity (mcd)		
Highway	**Ref. Pt.**	**Surface**	**Year**	**Striping**	**Year**	**Left Edge**	**Center**	**Right Edge**
65	47	Seal Coat	2009	All Weather	2009	244		
4	163	Seal Coat	2007	Latex	2010	325	227	263

Hwy 65 @ Reference Point 46.827

Hwy 4 @ Reference Point 162.998

Figure 16. Highways 65 and 4 Pavement Marking Performance

Additional Observations

The field visit resulted in a number of other pavement marking practice and performance observations are summarized below:

Rumble Stripes

- Figure 17 shows an example where the seal coat surface stops prior to the location of the edge line rumble stripe. This provides vertical protection for the marking from snow plow blades and the smoother surface allows for better retroreflectivity.

Figure 17. Rumble Stripe Placement Outside of Seal Coat

- Figure 18 shows an example of rumble stripe damage which was not caused by snow plows. As shown, there are large pieces of marking material missing in the bottom "trough" of the rumble. Whether this was a reaction to the extra fog sealant in the bottom of the rumble or caused by the freezing/thawing of water is unknown but should be further investigated.

Figure 18. Rumble Stripe Damage

- Micro or seal coat surfaces placed over existing pavement markings do not adhere to the old stripe very well. Fog sealants are typically used as a primer over the old stripe to improve adhesion. This is a particular problem when the existing edge line has been moved out to create a rumble stripe as shown in Figure 19 (where both stripes are visible).

Figure 19. Adherence to Existing Markings

Pavement Marking Damage

- Pavement marking damage on challenging surfaces was not restricted to latex, AWP, high-build paint, or epoxy. Figure 20 shows an example where tape was used on a micro surfaced roadway and the marking after the first year was damaged. Snow plow operations alone can greatly impact marking performance regardless of the surface type.

Figure 20. Damage to Tape after 1 Year on Micro Surface

- In some cases, pavement markings appear to suffer adhesion related issues where there are flat exposed aggregates as shown in Figure 21.

Figure 21. Aggregate Adhesion

- In some cases, the size of the aggregate appears to "break" up the mono-layer of marking material which causes rapid deterioration as shown in Figure 22.

Figure 22. Aggregate Size and Marking Damage

Pavement Marking Sequence

District staff varies their striping procedures by overlay type and roadway condition as summarized below. This information is generalized to contrast the two different approaches and does not reflect the many project by project conditional variations that arise.

- Seal Coat – Given the lower volumes, the initial striping may just include the center line. Since a fog sealant is used to help control rock loss, a two week waiting period is typical prior to striping the roadway. The typical striping sequence includes:
- Initially: Stripe the centerline with latex
- After two weeks: Stripe all lines with AWP
- After 1 to 2 years: Re-stripe all lines using Epoxy

- Micro Surface – With higher volumes, it is important to stripe all lines initially with a latex paint. After a 1 to 2 month cure time, a more permanent stripe is placed over the temporary markings. The typical striping sequence includes:
- Initially: Stripe all lines with latex
- After 1-2 months: Stripe all lines with AWP
- After 1 to 2 years: Re-Stripe all lines using Epoxy

Summary

A summary of findings for MnDOT district activities related to pavement marking performance on challenging surfaces:

- Marking performance is a problematic issue
- Experimenting with variety of materials (latex, AWP, High Build, Epoxy)
- Little success first year with any product
- Desire to standardize process to use same materials, methods, and improve effectiveness
- Shows need for comprehensive approach to determine procedure and materials to help make effective decisions (task 4)

Task 3 – Analysis

An analysis of current MnDOT practices, based upon findings from Tasks 1 & 2, identify key problematic issues along with potential solutions, and strategies to address pavement marking performance on challenging surfaces. This section summarizes the key findings.

MnDOT Guidance

The current Technical Memorandum No. 08-10-T-02, May 20, 2008 is limited in guidance for challenging surfaces given that it provides only two pavement marking material choices (paint and epoxy) based on remaining pavement service life (greater than or less than 2 years), ADT (greater than or less than 1,500) , and line type (edge versus centerline). With an expected life of at least 6 years for a challenging surface the current guidance recommends paint (roads less than 1,500 ADT) and epoxy (roads greater than 1,500 ADT). The failure rate for products over the first year of installation on a challenging surface has created a need to modify technical guidance.

Current Practice

In an effort to address the need for guidance on challenging surfaces, MnDOT districts have experimented with a variety of pavement marking products. This information is presented in Task 2 of this report, however, given the lack of documentation, an analysis of this information is limited to qualitative observations as summarized below:

District 4 (New Latex on Seal Coat)

- For yellow centerline, all readings were below MnDOT's expected 180 mcd initial retroreflectivity.

- There was a significant difference in retro by direction painted (80 versus 143 mcd) for one section of yellow centerline.
- The average retroreflectivity for white paint (on a right edge line) fell well below (average was 231 mcd) MnDOT's expected 275 mcd initial retroreflectivity.

District 3B

- **AWP on new** Micro surface: Initial readings for both white and yellow markings are above MnDOT expected thresholds.
- Epoxy on new seal coat: Failed (or close to failing) after one year on several sections ranging in ADT between 1,400 to 4,000 vehicles per day.
- Latex on a 3 year old seal coat: Initial retroreflectivity of 300 mcd compared to latex on new seal coat which had a retroreflectivity of less than 200 mcd.
- AWP on new seal coat: Initial retroreflectivity of 330 mcd exceeded MnDOT requirements of 280 mcd for a white edge line.
- AWP on seal coat after one year: The AWP failed with all retroreflectivity's being less than 140 mcd and an ADT of less than 1,400 vehicles per day.

Issues

A summary of findings for MnDOT district activities related to pavement marking performance on challenging surfaces identified the following issues:

1. Marking performance is a problematic issue based on input from the districts, field visits, and retroreflectivity data from Districts 3 and 4
2. Districts are experimenting with variety of materials (latex, AWP, High Build, Epoxy)
3. Little success first year with any product
4. Desire to standardize process to use same materials, methods, and improve effectiveness
5. Shows need for comprehensive approach to determine procedure and materials to help make effective decisions which is covered in Task 4

Solutions

Based on the data, findings, and a discussion with the project TAP, the following strategies were identified towards addressing the issue of pavement marking performance on challenging surfaces.

1. Experiment with different materials/methods
2. Develop pavement marking strategy to match the roadway life cycle
3. Develop guidance for districts

The above solutions are based on the following assumptions:

1. Assume no changes to the current surface specifications
2. All solutions focus on pavement marking materials and installation practices
3. Conduct a comprehensive field evaluation of different pavement marking materials and installation practices
    - Material (thicker, harder, primer)

- Installation (equipment, directionality, line placement to avoid challenging surface)

Task 4 – Outline for Field Trial

The research team worked with the project TAP to develop an outline for a future field trial. The field trial will evaluate the marking performance for different combinations of pavement marking materials and installation practices on challenging surfaces. The field trial includes:

Potential Materials

The list of potential pavement marking products to be evaluated are noted below.

- Latex
- High Build
- Visilock
- Thermo
    - Spray
    - Extruded
- Epoxy
- MMA
- Polyurea

Roadway Characteristics

The field trial will be conducted on both four-lane divided and two-lane roadways and will include both yellow (yellow edge and centerline) and white (white edge and skip) pavement markings on both micro surface and seal coat roadways. Example test sections are shown in Figure 23 below.

Figure 23. Example Roadway Characteristics

Application Options

The field trial will consider the benefits of a primer coating of material impacts the performance of the permanent striping. The trial will consider different glass bead delivery systems to try and improve retroreflectivity and directionality.

Test Deck Layout

As shown in Figure 24, the field trial will evaluate each product (Product A) over three 500 foot segments as noted below.

Year 1:
Segment 1 – Product A over seal coat and/or micro surface
Segment 2 – Same as 1, but over a primer
Segment 3 – Control section (latex)

Year 2:
Segment 3 – Product A over 1-year old latex

This process will be repeated for each product. Testing will extend through the life of the product or a maximum of 3 years.

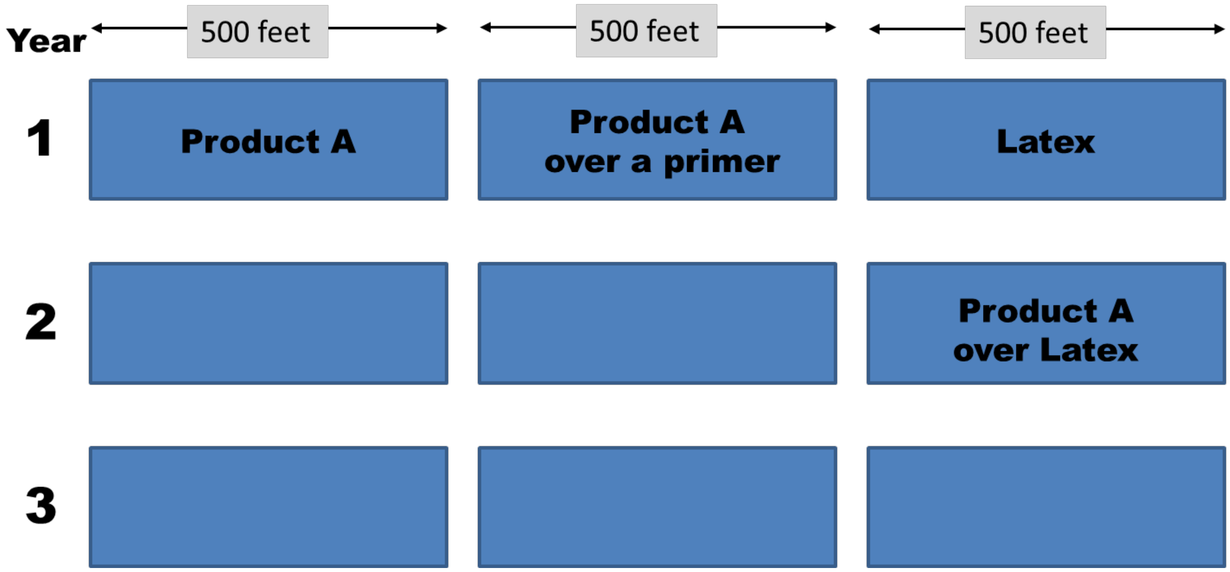

Figure 24. Test Deck Layout

Test Deck Evaluation

The following parameters will be considered for the life of the evaluation:

- Installation conditions
- Retroreflectivity by direction
- Presence
- Failure mechanism (rock loss, bond)

Measurements will be taken per the following schedule:

- Year 1 after installation and before winter
- Year 2 spring and fall
- Year 3 spring and fall

Chapter 3
Summary

This project is a beginning point for MnDOT towards an organized approach in addressing pavement marking practices on challenging surfaces. These project findings will be used in conjunction with the resulting field trial evaluations to improve MnDOT guidance and standard practice which will result in better performance, efficiencies, and roadway safety.

References

1. T. Wood, D. Janisch, and F. Gaillard, *Minnesota Seal Coat Handbook 2006.* Minnesota Local Road Research Board (LRRB), Minnesota DOT, June 2006, St. Paul, MN.

2. A. Johnson, *Best Practices Handbook on Asphalt Pavement Maintenance*. Minnesota T2/LTAP Program, Minnesota DOT, February 2000, St. Paul, MN.

3. T. Wood, R. Olson, E. Lukanen, and M. Wendel, *Preventive Maintenance Best Management Practices of Hot Mix Asphalt Pavements*. Minnesota DOT, May 2009, St. Paul, MN.

4. T. Gates, G. Hawkins, and E. Rose, *Effective Pavement Marking Practices for Seal Coat and Hot-Mix Asphalt Pavements*. Texas DOT, August 2003, Texas.

5. P. Macaluso (Louisiana Department of Transportation and Development), in discussion with the author, May 3, 2011.

6. Minnesota DOT, *MnDOT Policy for Pavement Marking Operations*, Technical Memorandum 08-10-T-02. May 2008, St. Paul, MN.