Comparison of Pavement Marking Systems
Waterford-Lyndon, Vermont

Initial Report 1998-2
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Reporting on Work Plan 96-R-4

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16. Abstract

The Vermont Agency of Transportation initiated this study to evaluate the performance characteristics of waterborne, epoxy, and thermoplastic traffic markings in a side-by-side comparison under identical environmental conditions. Of particular interest in this investigation will be the effect of snow plowing on the individual materials.

This report outlines the scope of the study, describes the materials under examination, explains the methods of testing, and details the initial inspection of the test sites.

Follow up reports will be issued throughout the duration of the study.

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Waterford-Lyndon, I-91

Introduction

This study investigates the field performance of three pavement marking materials which have been placed simultaneously on new bituminous concrete pavement. By testing the marking materials in a side-by-side study under identical environmental conditions, comparisons will be made concerning the service life and performance characteristics of each material.

The materials under study are epoxy, waterborne, and thermoplastic pavement markings. All markings in this study are 4" (100 mm) long lines, both white and yellow. These experimental features will be examined for deterioration due to weather, traffic, and winter maintenance. Performance features being examined are retroreflectivity, skid resistance, durability, and overall appearance.

Thermoplastic is the predominant durable marking material used in Vermont. Waterborne traffic paint is most often used for maintenance applications on older pavements and on portland cement concrete. Epoxy markings have been used experimentally by the Vermont Agency of Transportation on three previous projects, and in each case epoxy proved to be more durable than waterborne paint. Epoxy has lasted up to three years, whereas waterborne normally requires reapplication after one winter.

In Vermont, snow plow damage has been identified as the single most deleterious factor effecting the useful service life of thermoplastic pavement markings. Because of its high profile, thermoplastic is particularly susceptible to chipping from plow blades. Waterborne traffic paint, placed at 15 mils (380 μ), is less likely to be chipped, but is more susceptible to weathering. Epoxy promises to be more durable than waterborne and is less susceptible to plow chipping than thermoplastic. Because plow damage is such a critical factor in evaluating the service life of pavement markings, this study will address deterioration related to winter maintenance.

When the service life of each material has been reached, the data collected from this study will provide a useful gauge in predicting the service life of the individual materials on future projects and in selecting the appropriate marking material for a given application.

In addition, this project provides an opportunity to investigate how the various markings perform with the design pavement treatment, open graded friction course (OGFC). Raveling in OGFC has been found along thermoplastic edge lines. One theory for this distress is that hot applied thermoplastic fills voids in the pavement, voids which are essential for proper drainage. Water retention in the voids then puts the pavement at risk of freeze-thaw damage. Should premature raveling develop on this project, having different markings in place for comparison could be beneficial in assessing this theory.

The initial phase of the research involved observing the application of the materials to insure conformance with specifications. Each product was tested within one month of application to establish a baseline of measurements. Periodic inspection and measurements will be made over the service life of the materials. As each of the test materials reaches the end of its service life, the life cycle costs will be calculated and the relative cost effectiveness of the materials determined.

Product Descriptions

Thermoplastic

Linear Dynamics, Inc. (LDI) product SG-70 thermoplastic was placed over the entire project, excluding the two test sections. This material is used extensively by Vermont as a durable marking on interstate highways. The product is marketed as being able to withstand severe winters by maintaining elasticity during freeze-thaw cycles. The material is applied by extrusion as a heated liquid. Glass beads are intermixed in the heated material as well as dropped on the surface.

In the past, thermoplastic markings in Vermont were placed at 125 mils (3.2 mm). As of 1997, the Vermont Agency of Transportation specifies 90 mils (2.3 mm) thickness. The change was made in response to safety concerns raised by cyclists, many of whom have found that the high profile of thermoplastic jars two wheeled vehicles when crossing the lines. The thickness has been reduced to minimize this effect. There could be an added benefit since lowering the profile may also reduce plow damage.

Waterborne

Franklin Paint Company Hydrophast fast dry acrylic traffic paint was used in the waterborne test section. The material is suitable for both airless and air atomized spray equipment. For spray application the material may be heated, optimally to 110°F (43°C), but not to exceed 160°F (71°C). The manufacturer recommends an application thickness of 15 mils (380 μm). Ambient air should not be below 50°F (10°C) with relative humidity at or below 85%.

Epoxy

The epoxy material used on this project was LDI Super Lifeline III, a two-component (agent and catalyst) blend. Part A is composed of pigment, resin, and additives. Part B is an organic amine crosslinking agent. Applying epoxy requires equipment specifically designed to heat and meter the combination of components, which are mixed through opposing pressurized nozzles. Immediately after mixing, the pressurized material is redirected on to the pavement through an extrusion chute. The manufacturer specifies that the temperature of the blended components not exceed 110°F (42°C) during application. Manufacturer's specifications claim a no-pick-up time (ASTM D-711) of 10 minutes maximum with a 15 mil (380μm) application at 77°F (25°C), which is comparable in dry time to waterborne paint.

Project Description

This investigation is being conducted on the Waterford-Lyndon IM 091-3(7) interstate maintenance project, a pavement rehabilitation of 9.277 miles (14.93 km) northbound and 9.379 miles (15.09 km) southbound on Interstate 91. The project, as designed, calls for 90 mil (2.3 mm) thermoplastic, which was applied over the entire length of the project except in areas set aside for the experimental features. The pavement marking contract was awarded to L&D Safety Marking Corporation of Berlin, Vermont.

The project experimental features, a 1/2 mile (0.8 km) test section of epoxy and a 1/2 mile (0.8 km) test section of waterborne traffic paint, were placed at the following locations:

- Epoxy Pavement Markings: MM 133.2 to MM 133.7 (Southbound), Town of Lyndon
- Waterborne Traffic Paint: MM 133.7 to MM 134.2 (Southbound), Town of Lyndon

Linear Dynamics product SG-70 thermoplastic was placed in September of 1997. The application was reported to be in accordance with specifications with no deviations. Sections specified for the experimental markings were skipped by the thermoplastic truck. The striping contractor returned on October 2 to place the waterborne markings in the designated test section. Because of the small quantity, 1/2 mile (0.8 km), the contractor elected to use a hand cart rather than a hot paint vehicle. The waterborne lines were placed according to specifications.

At the same time that waterborne paint was being placed, white epoxy edge line was being placed by a crew sent from Linear Dynamics Inc. (LDI), the manufacturer of the epoxy material. The epoxy crew, likewise, elected to use a hand cart, one specifically designed for epoxy. According to the LDI technician, the catalyst was heated to 125°F (52°C) and the agent to 150°F (66°C). These temperatures conflict with the manufacturer's recommendation which limits the temperature to 110°F (43°C). The two components were mixed under pressure of 15 MPa (2000 psi) and sprayed on the pavement through a nozzle. Drop on glass beads were applied at a rate of 2.4 kg/L (20 lbs/gal.). Glass beads cannot be intermixed with epoxy.

Prior to applying the epoxy, a moisture test was performed by placing a strip of tar paper on the pavement then striping it with the heated material. The underside of the paper showed a high moisture content. In spite of this, the LDI technician was not concerned about the moisture and stated that the bonding action of the epoxy would not be affected by the high moisture content of the pavement and that an adequate bond would form.

The epoxy crew had trouble keeping the cart aligned with the stencil so that the initial 1500± feet of edge line is badly misaligned. The LDI crew stated that the cart they were using was primarily for working on test decks, and therefore had not been installed with a pointer. In addition to the alignment problem, there was heavy over-spray resulting in blurry edges. The cause of the over spray was probably attributable to excessive application pressure and/or the high temperature of the material, causing the epoxy spray to bounce off the pavement.

Dry time of the epoxy was recorded during the striping. Set-to-touch time was approximately 30 minutes under ambient temperature of ±50°F (±10°C) and pavement temperature of 67°F (19°C). This was much longer than anticipated, especially since the manufacturer claims a dry time of 10 minutes at 77°F (25°C). Even accounting for the difference in temperature, the dry time was excessive for a highway application. What is most troubling about the long dry time are the curing characteristics of epoxy. Whereas paint dries through evaporation of carriers, epoxy cures through a crosslinking of the two components. Consequently, epoxy does not form the initial film as does paint, but remains very liquid until such time that the crosslinking of the resins takes place. While paint offers some protection from splattering, tracking, and contamination from blowing debris while in its initial stage of drying, epoxy is very fluid until the crosslinking commences.

Part way into the striping, the operation was halted by the resident engineer because of the crooked lines. The next day, the striping subcontractor (L&D Safety Marking Corporation) took charge of the epoxy application, fitted the cart with a pointer, and completed the epoxy lines to the resident engineer's satisfaction.

Test Procedures

Two separate test sites were established for each material. Test sites will be referenced by their mile marker location, described as follows:

Marking Material	Supplier/Product Name	Test Site Locations
Thermoplastic	Linear Dynamics, Inc. SG-70	MM 130.50 MM 134.75
Epoxy	Linear Dynamics, Inc. Super Lifeline III	MM 133.45 MM 133.55
Waterborne	Franklin Paint Company Hydrophast Acrylic	MM 133.70 MM 134.00

Performance of the materials will be measured through field tests for retroreflectivity and skid resistance at the test sites detailed above. In addition, a durability assessment will be made of the overall condition of the markings, particularly damage from snow plowing, which will be estimated as a percentage of material lost.

Retroreflectivity is tested with the LTL 2000 retroreflectometer. Each material was tested at the two test sections referenced above, with ten readings at each site, five on the white edge line and five on the yellow barrier line.

Skid resistance is measured with the British pendulum skid tester, and expressed by the British pendulum number (BPN). Skid resistance tests were performed on white edge lines and on adjoining bare pavement for comparison.

The test sections will be examined after each winter exposure to determine the percentage of material lost to weather and plowing. At each test site, skid resistance and retroreflectivity tests will be performed to assess the deterioration of these performance features. In addition, the thermoplastic edge lines will be inspected for water retention and possible adverse effect on the OGFC pavement.

Post Construction Inspection and Testing

The project markings were inspected on October 10, 1997. All materials had been placed within the past month and were essentially in new condition. The markings were inspected for consistency of application, color, and bead content and were tested for retroreflectivity and skid resistance.

Post Construction Test Results
October, 1997

Material Test site	Retroreflectivity (mcdl) White	Retroreflectivity (mcdl) Yellow	Skid Resistance (BPN) Markings	Skid Resistance (BPN) Bare Pavement
Thermoplastic				
MM 130.50	222	90	54	73
MM 134.75	177	82	60	64
Epoxy				
MM 133.45	232	192	80	69
MM 133.55	110	194	56	68
Waterborne				
MM 133.70	39	145	41	52
MM 134.00	55	96	44	60

Thermoplastic

The overall appearance of the thermoplastic markings was considered good. The application showed consistent thickness, well defined edges, and good color in both the white and yellow lines. Results of retroreflectivity and skid resistance tests are considered typical for newly applied material. In spite of the lower profile, 90 mils (2.3 mm) versus 125 mils (3.2 mm), the material retains the solid, crisp appearance inherent with thermoplastic.

Waterborne

The waterborne lines appeared to be of correct application thickness and had good bead coverage. In terms of color, the white lines were inexplicably dull. This was corroborated through retroreflectivity testing, where the white waterborne markings gave somewhat low values for freshly applied material. Values of at least 60 mcdl are expected, as opposed to the 39 mcdl and 55 mcdl measured. By comparison, the yellow lines had readings of 145 and 96 mcdl, which are very high for new yellow waterborne, which usually averages 50 mcdls. Several factors could be responsible for the relatively low mcdl readings on the white lines. The most obvious is the texture of the OGFC. Because of the deep voids characteristic of OGFC, there is less area for the paint to adhere to than with dense graded mixes. This, in effect, reduces the reflective surface area, and in turn, the retroreflectivity.

Aside from the texture of the pavement, it was also noted that the surface of the white lines had smudged. Several causes have been examined for the discoloration. Vehicle tracking was ruled out since the smudging is found over the entire length of the test section rather than in isolated locations as would be expected from tracking. Another cause could be bleed-through of asphalt cement. This usually results from unaged asphalt and/or high temperature of the paint. Since the asphalt cement had aged for two weeks (as recommended by the thermoplastic manufacturer), and the paint was applied unheated, the conditions were not conducive to bleed-through.

By comparison, the yellow lines are bright in color and don't appear to be smudged; although it is possible that the discoloration is present but less visible against the yellow color. Because of the relatively rapid deterioration (low durability) of waterborne traffic paint, the dull color and marginally low retroreflectivity are not considered serious shortcomings within the context of this investigation.

Epoxy

As noted in the Project Description, there was difficulty in getting an acceptable application of epoxy. Although the alignment was erratic at first and there were problems with over-spray, test panels showed that the final product was within the specified 15 mil (380 μ) thickness. For purposes of this study the application was considered acceptable. Although poor in appearance at time of placement, the epoxy over-spray will most likely be less noticeable after some weathering.

In spite of the initial problems, the epoxy markings have retroreflectivity values exceeding those of thermoplastic, which with its solid profile, are normally quite high. In addition, the skid resistance values for the freshly applied epoxy are good.

Life Cycle Cost Analysis

According to Transportation Research Board data[1], pavement markings of the types being studied here have been shown to have life cycle costs as presented below. Also presented are the actual material costs for the Waterford-Lyndon project.

	Material	Average Lifetime	Cost Range *	Project Costs *
•	Thermoplastic	4.5 years	$ 0.20 - $ 0.80	$ 0.31
•	Epoxy	2.0 years	$ 0.17 - $ 0.33	$ 0.31
•	Waterborne	0.63 years	$ 0.02 - $ 0.06	$ 0.07

* per linear foot of 4" line (installed)

Actual costs for thermoplastic and epoxy on the Waterford-Lyndon project are within national averages. Waterborne was bid slightly higher than national averages; but since this was only a ½ mile application, the extra cost can be attributed to economy of scale. The average lifetimes of epoxy and waterborne appear consistent with Vermont's experience. The average of 4.5 years of service life for thermoplastic may be somewhat optimistic for extreme northern states with "bare roads" maintenance policies, such as Vermont, because of plow damage.

Summary of Post Construction Inspection

- The thermoplastic lines show good workmanship and exhibit performance characteristics typical for newly placed material.

- The waterborne lines are acceptable for the purpose of this study, although the white lines are inexplicably dull in color and have marginal retroreflectivity. The yellow lines are considered typical for new material.

- Although the epoxy lines have good initial retroreflectivity and skid resistance, the quality of the application was disappointing.

[1] Pavement Marking Materials: Assessing Environment-Friendly Performance, Anthony L. Andrady, Transportation Research Board, 1997 *National Cooperative Highway Research Program, Report 392*

Follow Up

The pavement markings will be examined periodically to determine the extent of deterioration. An evaluation of the following features will be reported:

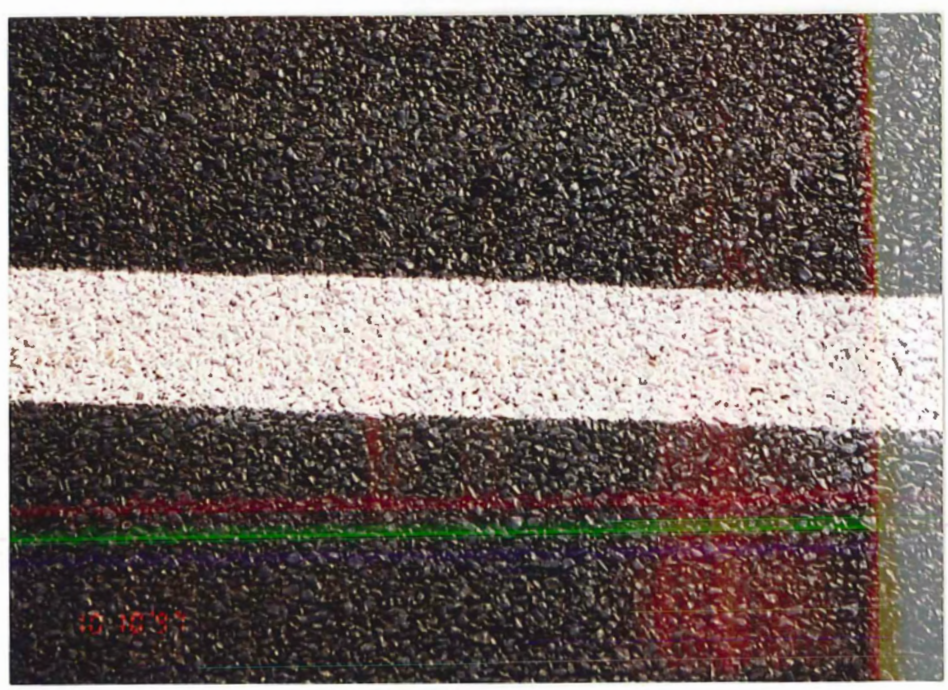
- Overall condition, percentage of material lost
- Retroreflectivity
- Skid resistance

Results of the next inspection will be presented in an update report. It is expected that the waterborne lines will be nearly obliterated.

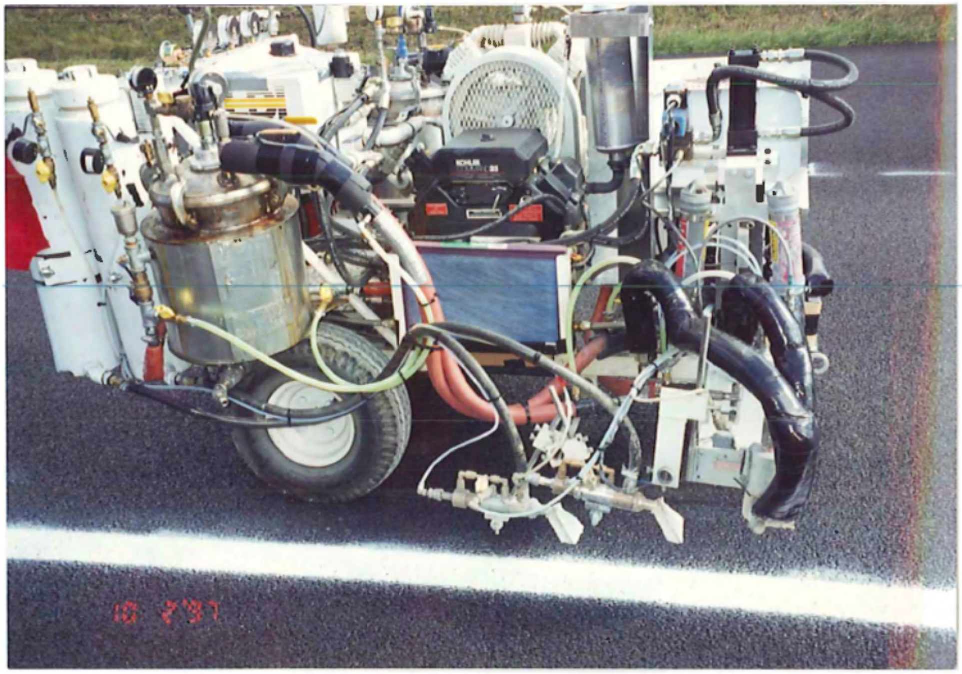
Thermoplastic edge line,
Photo taken 11-2-97,
MM 130.50

Epoxy edge line,
Photo taken 11-2-97,
MM 133.50

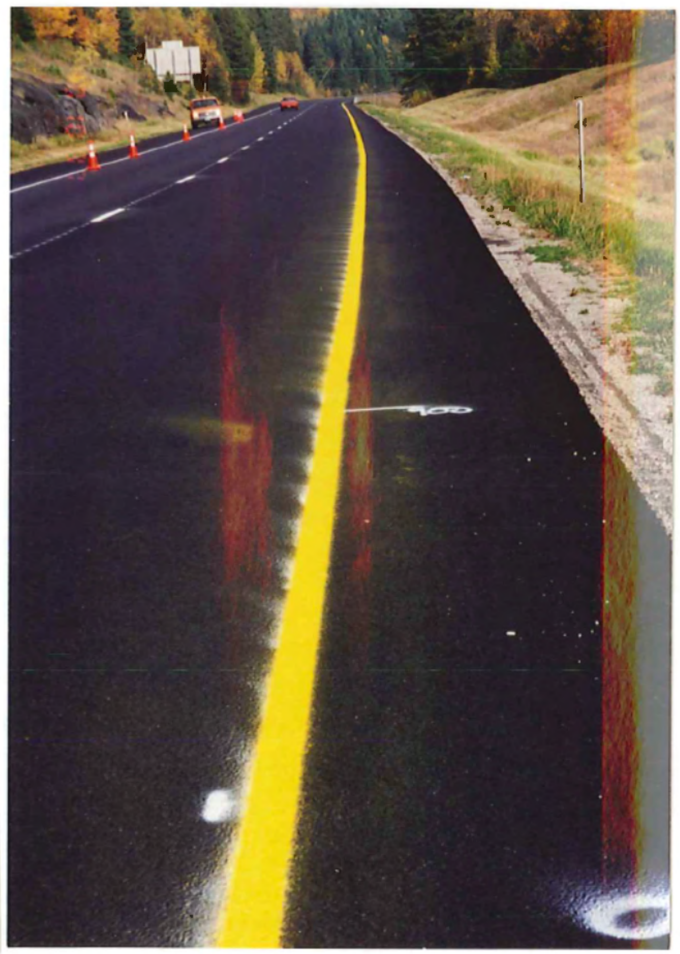
Waterborne edge line,
Photo taken 11-2-97,
MM 134.00



Epoxy applicator



Applying epoxy
10-2-97



Epoxy barrier line
Note heavy over spray