Premark® 20/20 Flex High Skid Resistance Thermoplastic
Williamstown, Vermont

April 2002
Reporting on Work Plan 2000-R-4
Initial Report

State of Vermont
Agency of Transportation
Materials and Research

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16. Abstract

This report describes the performance of a performed thermoplastic pavement marking material designed to provide high skid resistance. This initial report details the performance of the material in a test site application.

This report documents the performance of the pavement marking material in a low traffic volume, but high winter maintenance area. Performance data includes retroreflectivity, skid resistance, and photographic documentation.

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Introduction

With increased demands on our highway transportation infrastructure to serve both motorized and non-motorized vehicles, alternative methods are being sought to better delineate separate travel lanes for these different vehicle types. One method of delineation is to use color to define these travel lanes. The use of colored lane markings has been practiced in some European cities and in the City of Portland, Oregon with reported success.

This study was initiated by a request from the Vermont Agency of Transportation's District #5 Administrator to better delineate a bike lane across a bridge in the City of South Burlington. Bridge #68, located on Williston Road (US Route 2), passes over Interstate I-89 at Exit 14. This travel corridor received an estimated annual daily traffic volume (AADT) of 56900 in 2000.

Many alternatives to produce the colored lanes were considered including paint and colored asphalt. The product selected for an experimental application was Premark® 20/20 Flex High Skid Resistance preformed thermoplastic pavement markings. Presently, this preformed thermoplastic marking material is being used by the City of Portland, Oregon to delineate bike lanes across certain ramp crossings.

This initial investigation evaluates the performance of the Premark material at a test site in the Town of Williamstown. Its performance, if successful, may warrant its use on the bridge in the City of South Burlington. Although this site does not receive high daily traffic volumes, it does incur high winter maintenance activities that typically induce damage on such markings. It also represents the material's ability to perform where traffic wear is minimal but winter maintenance activities are frequent, such as would be experienced in a bike lane adjacent to a highway.

Product Description

Premark® 20/20 Flex High Skid Resistance preformed thermoplastic pavement marking material is manufactured by Flint Trading Inc. of Thomasville, NC. The factory-produced material is composed of an ester modified rosin with aggregates, pigments, binders, abrasives, and glass beads. A portion of the glass beads is intermixed in addition to glass beads and quartz abrasives applied to the surface. The material is available in various colors; blue was selected for the preliminary test site evaluation.

The preformed thermoplastic markings are torch applied which creates a chemical bond with the pavement. The material is available in widths up to a 24" and in thicknesses of 0.09 inches (90 mil) and 0.125 inches (125 mil). In February 2000, the cost of the 125 mil material was $3.11 per foot.

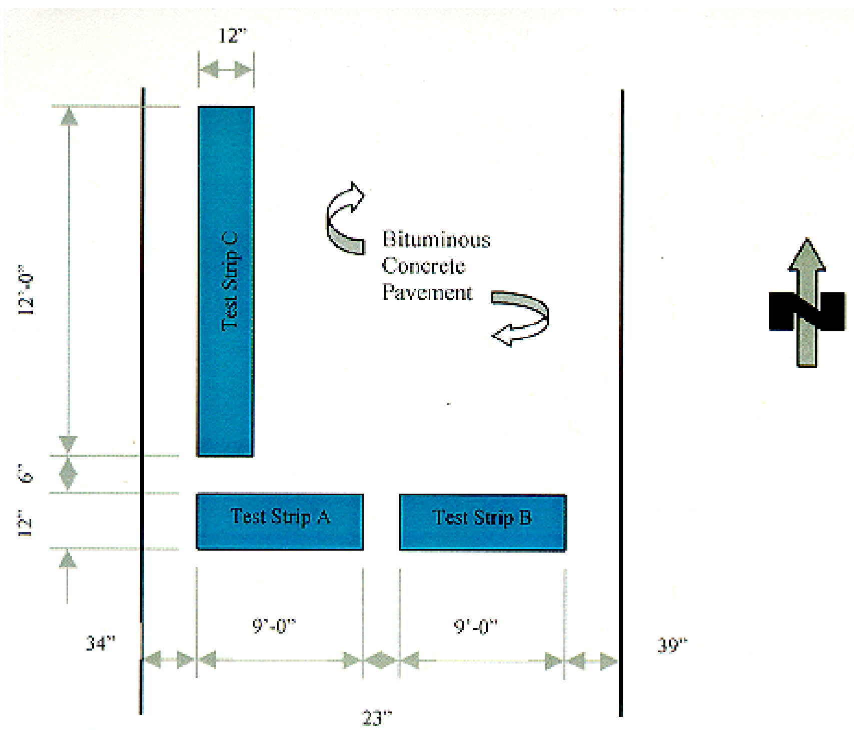
Test Site Evaluation

Location

A preliminary test site was established to evaluate the performance of the material prior to considering its use for bike lane delineation on the Vermont highway system. The Premark® 20/20 Flex High Skid Resistance preformed thermoplastic pavement marking test site is located on the driveway to the District #6 state maintenance garage off VT Route 64 in the Town of Williamstown.

The site, with a 1 to 1 ½ year-old bituminous concrete surface, was selected for its plowing frequency during the winter maintenance season with varying snow removal equipment, including plow trucks with wings and graders. In addition to monitoring the material's durability, retroreflectivity and skid resistance data were collected.

The layout of the test site, as shown in Figure 1, was designed to test the material both parallel and perpendicular to traffic flow. A total of three, 125 mil thick test strips were placed. One strip, 12 feet by 1 foot, was placed longitudinally in an outer wheel path and two additional strips, 9 feet by 1 foot each, were placed transversely, across both travel lanes of the drive.



<u>Figure 1.</u> Test Site Layout – Williamstown, Vermont.

Installation

On August 22, 2000, a representative from Flint Trading, Inc. installed the preformed thermoplastic material using the propane hand torch method. The weather was dry with an ambient air temperature of 60^{o} F.

The installation process, as shown in Figures 2, 3, and 4, began by preheating the clean pavement surface. The purpose of this was twofold, to dry the surface and soften the asphalt binder in the bituminous pavement. The material was then placed over the preheated area and a torch passed over it until heated throughout and good adhesion was obtained.

While the material was still soft, all four edges of Test Strip A and the northern, one foot wide edge, of Test Strip C were feathered with a straightedge to produce tapered faces with a maximum 1:1 slope. Test Strip B had no edges feathered.

To check for adhesion of the thermoplastic material to the asphalt, a chisel test was performed on Test Strips A and B. After the material solidified, a small section was removed with a hammer and chisel, as shown in Figure 5. Both Test Strips A and B had asphalt adhering to the material when pulled up, indicating a bond between the pavement and the marking material. Placing the chiseled piece back in place and heating it with the torch resealed these areas.

Figure 2. **Preheating pavement surface.**

Figure 3. **Heating preformed thermoplastic material.**

Figure 4. **Feathering edge of material.**

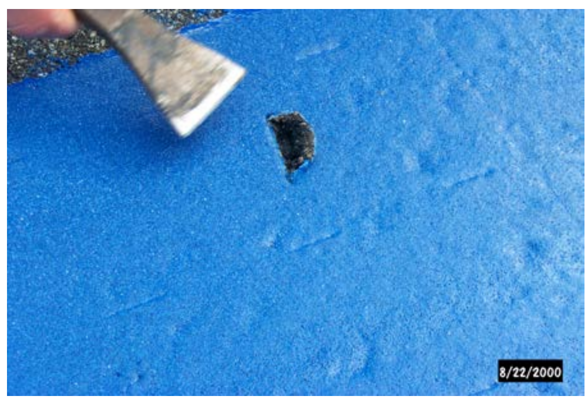


Figure 5. **Chisel test.**

Performance Evaluation

Testing and Equipment

Retroreflectivity and skid resistance values were collected following the initial installation and three additional times thereafter over a period of 1 ½ years. Retroreflectivity data was collected in accordance with ASTM E1710-97, with one exception; data collected on Test Strips A and B were taken perpendicular to traffic flow due to the transverse placement of the markings to the driveway. The values collected are presented in Table 1. Data was collected with an LTL 2000 retroreflectometer. The equipment was calibrated to a standard calibration block prior to taking readings on each date.

Readings collected in February 2002 were done in accordance with a test procedure created by the Vermont Agency of Transportation, Materials and Research Section. The procedure, designed to allow for the collection of retroreflectivity data in cold weather climates, includes a cleaning procedure and a manufactured Plexiglas™ box supplied with a heat source to generate a minimum ambient air temperature of 40^{o}F as specified in ASTM E1710-97. Figures 6 and 7 show the markings before and after the cleaning process, respectively. And, the testing apparatus is shown in Figures 8 and 9.

Figure 6. **Markings prior to cleaning.**

Figure 7. **Markings after swept, washed, and dried.**

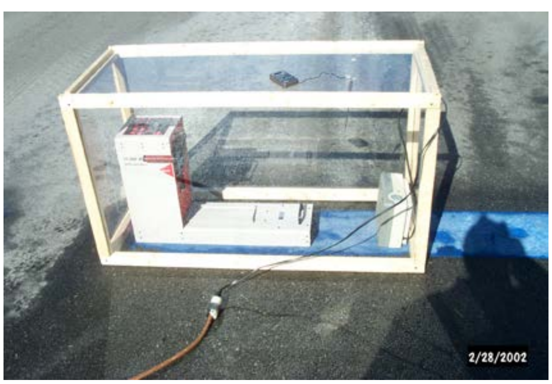


Figure 8. **Cold climate testing apparatus.**

Figure 9. **Temperature reading within Plexiglas™ box.**

Skid resistance values were collected, as shown in Figure 10, using a British Pendulum Tester following the procedure outlined in ASTM E303-93. Values collected are presented in Table 2. MASTRAD, Quality & Test Systems in Bardsey Leeds, United Kingdom, calibrated the instrument in October 2001. Refer to Appendix A for a copy of the calibration test certificate.

Values collected prior to the calibration may be evaluated comparatively to readings taken on the same test date. Those taken after may be best evaluated independently in comparison to the adjacent asphalt value.

Figure 10. Skid test with British Pendulum Tester.

Retroreflectivity

The following table represents retroreflectivity data collected for the pavement marking material from the time of installation to 18 months thereafter. The manufacturer states that the increase in skid resistance decreases the retroreflectivity value of the material. And, due to the color, blue, the values are lower than the commonly used traffic marking materials colors, white and yellow.

RETROREFLECTIVITY (mcd)(m^{-2})(lux^{-1})				
	Date			
	August 22, 2000 (at installation)	**April 24, 2001** (8 months)	**August 29, 2001** (12 months)	**February 28, 2002** (18 months)
	Ambient Air = 60°F	Ambient Air = 75°F	Ambient Air = 66°F	Ambient Air =28°F (56-63°F in 'Box')[3]
Test Strip A[1] (perpendicular to traffic)	23	21	35	23
Test Strip B[1] (perpendicular to traffic)	19	22	31	20
Test Strip C[2] (parallel to traffic)	26	30	40	36

[1] Test Strips A & B: Values based on average of (4) readings.
[2] Test Strip C: Values based on average of (5) readings.
[3] Readings taken with the use of experimental apparatus for data collection in cold weather climates (see Appendix A).

Table 1. Average Retroreflectivity Values

The values presented in Table 1 indicate an average increase in the retroreflectivity of the material during its first year of performance. With the exception of Test Strip A's average value on April 24, 2001, the test strips increased on each test date producing an overall increase of more than 50% after the first year. An initial increase in values commonly occurs in marking materials as they are exposed to wear and abrasion, resulting in the exposure of the embedded glass beads.

Between 12 and 18 months of service, the values for all the test strips declined, with two of the three test strips approaching their initial value at installation. More details of the readings collected in February 2002 are represented in Appendix B.

Skid Resistance

The following table represents skid resistance data collected for the pavement marking material from the time of installation to 19 months thereafter. All readings taken on the marking material were collected in the center of the test strip. Five readings at two independent locations were collected on each test strip, for a total of 10 readings per strip. According to the manufacturer's specification, this product "shall upon application provide a minimum skid resistance value of 60 BPN when tested according to ASTM: E303."

<table>
<tr><th colspan="9">SKID RESISTANCE
BPN (british pendulum number)</th></tr>
<tr><td rowspan="3"></td><td colspan="2">August 22, 2000
(at installation)</td><td colspan="2">April 24, 2001
(8 months)</td><td colspan="2">August 29, 2001
(12 months)</td><td colspan="2">April 2, 2002
(19 months)[1]</td></tr>
<tr><td colspan="2">Ambient Air = 60°F</td><td colspan="2">Ambient Air = 75°F</td><td colspan="2">Ambient Air = 66°F</td><td colspan="2">Ambient Air = 43°F</td></tr>
<tr><td>Average</td><td>Overall Average</td><td>Average</td><td>Overall Average</td><td>Average</td><td>Overall Average</td><td>Average</td><td>Overall Average</td></tr>
<tr><td>Test Strip A[2]</td><td>67.4</td><td rowspan="3">65.0</td><td>82.6</td><td rowspan="3">82.9</td><td>85.5</td><td rowspan="3">78.9</td><td>81.1</td><td rowspan="3">79.2</td></tr>
<tr><td>Test Strip B[2]</td><td>60.9</td><td>82.9</td><td>69.6</td><td>75.6</td></tr>
<tr><td>Test Strip C[2]</td><td>66.8</td><td>83.2</td><td>81.7</td><td>81.0</td></tr>
<tr><td>Asphalt[3]</td><td></td><td>86.5</td><td></td><td>93.8</td><td></td><td>91.1</td><td></td><td>84.2</td></tr>
<tr><td>% Difference
(Premark vs. Asphalt)</td><td></td><td>-33%</td><td></td><td>-13%</td><td></td><td>-15%</td><td></td><td>-6%</td></tr>
</table>

[1] British Skid Pendulum has been calibrated at a laboratory to meet the requirements of ASTM E303-93.
[2] Test Strips A, B, C: Average based on (10) readings, with five readings at two separate locations per strip.
[3] Readings taken on asphalt were adjacent to the corresponding test strips: (4) readings in August 2000, (15) readings in April 2001, August 2001, and April 2002.

Table 2. Average Skid Resistance Values

The values presented in Table 2 indicate that the product has maintained a high skid resistance value over the 19 month evaluation period. The preformed thermoplastic material skid resistance increased an average of 28% after eight months of service. After 19 months the markings continued to maintain skid resistance values higher than the initial specified value by the manufacturer.

A comparison between the pavement marking material and the adjacent asphalt pavement indicates that both materials' frictional characteristics are similar. Although the asphalt pavement is slightly higher in value, both surfaces have maintained a skid resistance value equal to or better than MASTRAD, Quality and Test Systems' highest suggested minimum skid resistance value of 65 BPN in wet conditions. These values are documented in their "Skid Tester Manual," published in 2001. Refer to Appendix C for a copy of the table of values.

Durability

After eight months of service, including one winter maintenance season, the 125 mil thick preformed thermoplastic marking material remained well intact. Test Strip A, with all four edges feathered and placed perpendicular to the traffic flow, exhibited the most distress. As seen in Figures 11 and 13, the south edge of the material and two corners experienced chipping. Test Strip B, placed adjacent to Test Strip A and perpendicular to traffic flow, had no edges feathered and showed similar signs of distress in the same locations but of a lesser degree, as shown in Figures 12 and 14. Test Strip C, with only the northern one-foot edge feathered, and placed parallel to traffic flow experienced little distress with only one corner chipped, as shown in Figure 11.

Figure 11. Test Strip A and C after eight months.

Figure 12. Test Strip B after eight months.

Figure 13. Test Strip A (west end) with feathered edge after eight months.

Figure 14. Test Strip B (west end) without feathered edge after eight months.

During a site visit in March 2001, it was observed that the abrasive characteristics of the material allowed for small particles of sand to be lodged within the marking material as shown in Figure 15. Future site visits revealed that the sand residual washed out over time with the rain.

<u>Figure 15.</u>   Sand particles lodged in material.

After 12 months of service, the preformed thermoplastic revealed a change in the material's surface along the edges exposed to wear and plow abrasion as seen in Figure 16. The change in the material's characteristic may affect the skid resistance along these leading edges since a loss of some abrasive material occurred. The damage extended approximately 1 ½ inches into the strip at its grooved dimension.

In addition, the material began to develop 'pin holes' as shown in Figure 17. According to technical staff at Flint Trading, Inc., this is likely the result of a year of wear on the material that caught up to air bubbles that were present at the time of installation. These air bubbles were likely developed during the heating of the material from trapped moisture or gases in the pavement. These holes are considered only cosmetic and reported not to effect the performance of the material or its service life by the manufacturer.

<u>Figure 16.</u>   Test Strips A and B after 12 months of service.

<u>Figure 17.</u>   'Pin Hole' development.

Figure 18. Detail of plow damage after 17 months of service.

Summary

In July 1999, the City of Portland in Oregon published a report, "Portland's Blue Bike Lanes: Improved Safety through Enhanced Visibility," documenting its experience with various materials for enhanced bike lane delineation. Areas selected for the study were those "with a high level of cyclist and motorist interaction, as well as history of complaints" (2). The areas identified were exit ramps, right-turn lanes, and entrance ramps, where motorists crossed the bike lane. In their evaluation they concluded that after a year in place it "is holding up well at six of eight sites" (4). They believe those areas performing less than favorable may be the result of an incorrect installation.

Currently there are no established minimum retroreflective values for pavement marking materials adopted by the State of Vermont's Agency of Transportation nor AASHTO. The American Society for Testing and Materials (ASTM) has published a specification, D6359-99, "Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments," with values specified for white and yellow markings within 14 days of installation. These values are 250 (mcd)(m^{-2})(lux^{-1}) for white and 175(mcd)(m^{-2})(lux^{-1}) for yellow. The average value of the blue colored material placed in Williamstown averaged 26 (mcd)(m^{-2})(lux^{-1}) after 18 months of performance, indicating that little retroreflectivity value is provided. These readings corroborated findings in the City of Portland report which states, "the blue appears quite bright, it is not as visible as anticipated in low light conditions" (4).

As with retroreflectivity, Vermont has not established a minimum skid resistance value for pavement marking materials. Most preformed pavement marking materials provide an average minimum initial skid resistance value of 45 BPN or higher. The manufacturer's specification for Premark® 20/20 Flex High Skid Resistance preformed thermoplastic states a minimum installation value of 60 BPN will be provided. Data collected during this initial investigation validated that the product exceeded the minimum installation value and after 19 months of service continued to perform above that value. The City of Portland report states that after being in place almost a year, "Cyclist are pleased […] with the texture; it is not slippery" (4). Data collected by the City of Portland regarding skid resistance and retroreflectivity was based on subjective opinions and surveys.

The site selected for the initial evaluation of this product was located in an area that experiences frequent plow activity. Although there is no continuous traffic flow at this test site, it may best represent the minimal vehicular traffic flow that may occur in a bike lane adjacent to a highway. Test Strip C's placement, longitudinal to traffic flow, may best simulate the effect of snow removal maintenance and wear in applications parallel to traffic. Test Strips A and B may provide insight to the material's performance in a transverse-to-traffic scenario, such as those applications in the City of Portland, Oregon. According to the Bicycle Coordinator for the City of Portland, Oregon, after three years of service some locations were outperforming others. To his knowledge, since the material's use in 1999, it has been replaced once at most of the sites, the primary reason for this, he believed was associated with the product's installation.

Follow-Up

An installation of Premark® 20/20 Flex High Skid Resistance preformed thermoplastic pavement marking material is scheduled to be placed on Bridge 68, on US Route 2, in the City of South Burlington in 2002, for delineation of a bike lane. If constructed, data will be collected to include retroreflectivity, skid resistance, and photographic documentation. In addition, subjective opinions pertaining to the product's performance may be collected. Additional retroreflectivity data may be gathered at the Williamstown site to evaluate seasonal trends. Reports will be published as warranted.

References

1. Hales, Charlie, et.al.,“ Portland’s Blue Bike Lanes: Improved Safety through Enhanced Visibility,” City of Portland, Office of Transportation, July 1999.

Appendix A

Skid Tester Calibration/Test Certificate

Customer	MASTRAD / STATE OF VERMONT
Machine Number	6695
Certificate Number	C1160
Date	21/09/01
Standard	BS EN 1097-8

		Standard		Tolerance	Recorded	
Swinging Arm - Mass	gms	1500	W_1	+/- 30	1496	W_2
Distance of COG from COO	mm	410	L_1	+/- 5	408	L_2
'F' scale vertical distance	mm	85		+/-0.5	85	
Slider force	N	22.2		+/-0.5	22.0	
Calibration Weight	gms	2263		+/- 51	2247	
Change in slider force	N/mm	0.2		<-0.2	0.17	
Pointer length	mm	305		+/- 0.5	305	
Pointer mass	gms	85		<-85	76	

Notes

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Signed By:

Appendix B

Vermont Agency of Transportation
Technical Services - Materials and Research Section
Marking Investigation

Project Name & Number:	Premark	Town:	Williamstown
Date:	02/28/2002	Location:	District Garage
Tested By:	D.Connolly, C. Pierce	Weather	Clear
Mile Marker:	N/A	Temperature:	Air: 27.8 °F Pavement: 41°F- 43 °F

Notes: Picture 69-64 are pictures before cleaning and set-up
Picture 50 - 48 temperature with heater, Picture 48-47 are without heat.
Box "B" used heat to warm up the box then the heat source cut out then the sun kept box at temperature between 56.6 °F and 60.7 °F.
Box "A" used heat source and got the box up to 93.2 °F and then took out heat source and let the sun do a green house effect.
Box "C" had to use heat source on last reading to get temperature up a little because sun went a way.

"C"

Pavement Temp.	Reading	Air Temp
49 °F	41	56.1 °F
49 °F	41	56.3 °F
49 °F	33	56.8 °F
49 °F	36	60.6 °F
49 °F	28	57.5 °F

Picture 54-50, & 46

"A"

Pavement Temp.	49 °F	49 °F	49 °F	49 °F
Reading	40	25	12	16
Air Temp.	62.6 °F	60.6 °F	60.8 °F	63.0 °F

Picture 59-54

"B"

Pavement Temp.	49 °F	49 °F	49 °F	49 °F
Reading	14	13	19	35
Air Temp.	Range 56.6 °F- 60.7 °F			

Picture 64-59

Comments: Didn't record individual air temperatures in box on "B" because it was an after thought but the temperature range was 56.6 °F- 60.7 °F.

Appendix C

Table 1

Suggested minimum skid resistance values (wet conditions)

Category	Type of Site	Value
A	Difficult sites such as:- (I) Roundabouts (ii) Bends with radius less than 150 m on unrestricted roads (iii) Gradients, 1 in 20 or steeper, of lengths > 100 m (iv) Approaches to traffic lights on unrestricted roads	65
B	Motorways, trunk and class 1 roads and heavily trafficked roads in urban areas (carrying more than 2000 vehicles per day)	55
C	All other sites	45

Rough textured surfaces where tyre tread pattern would have a negligible effect. Smooth and patterned tyres would generally be equally effective on these surfaces.

Medium textured surfaces where some tread pattern effect would exist. Vehicles having smooth tyres would experience a skidding resistance slightly lower than the value indicated by the tester.

Smooth-textured surfaces where the effect of tread pattern may be large.

(I) On roads where speeds are high, a simple measure of surface texture, the 'texture depth', may be determined by the 'sand patch' method. A known volume of fine sand is poured in a heap on the road, and spread to form a circular patch so the small valleys on the road are filled to the level of the peaks. The 'texture depth' is the ratio of the volume of sand to the area of the patch (calculated from the measured radius).

Source: MASTRAD Quality and Test Systems, "Skid Tester" User Manual, Version 3.0, published June 20, 2001.

During a site visit in March 2001, it was observed that the abrasive characteristics of the material allowed for small particles of sand to be lodged within the marking material as shown in Figure 15. Future site visits revealed that the sand residual washed out over time with the rain.

Figure 15. Sand particles lodged in material.

After 12 months of service, the preformed thermoplastic revealed a change in the material's surface along the edges exposed to wear and plow abrasion as seen in Figure 16. The change in the material's characteristic may affect the skid resistance along these leading edges since a loss of some abrasive material occurred. The damage extended approximately 1 ½ inches into the strip at its grooved dimension.

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Figure 16. Test Strips A and B after 12 months of service.

Figure 17. 'Pin Hole' development.