Evaluation of 3M Stamark High Performance Wet Reflective Tape Series 380WR ES Durable Tape Final Report

February 2011

Report 2011 – 2
Reporting on Work Plan 2008-3

State of Vermont
Agency of Transportation
Materials and Research Section

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Date: Feb 10, 2011

1. Report No. 2011-2	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Evaluation of 3M Stamark High Performance Wet Reflective Tape Series 380WR ES		5. Report Date February 2011 6. Performing Organization Code
7. Author(s) Jason Tremblay, M.S., Jennifer M. V. Fitch P.E.		8. Performing Organization Report No. 2011-2
9. Performing Organization Name and Address Vermont Agency of Transportation Materials and Research Section National Life Building Drawer 33 Montpelier, VT 05633-5001		10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Federal Highway Administration Division Office Federal Building Montpelier, VT 05602		13. Type of Report and Period Covered Final (2008-2009) 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

In association with a federally approved work plan, WP 2008-3, 3M Series 380WR ES Permanent Durable Tape was applied to a portion of the South Burlington – Colchester project, IM 089-3(60), located along I-89 southbound between mile markers 88.502 and 88.833. According to 3M, the product is a patterned pavement marking tape which provides high retroreflectivity under both wet and dry conditions using abrasion-resistant microcrystalline ceramic beads that are bonded in a highly durable polyurethane topcoat. Test sites were established and monitored over an eleven month period along all 29 experimental skip markings in addition to 10 control markings comprised of 3M LPM 1200 polyurea.

Overall, retroreflectivity values degraded quickly with the onset of traffic and winter maintenance activities. Initial retroreflectivity levels were found to be 401 and 698 mcd/m^2/lx for the experimental and control markings, respectfully. Following the first winter season, retroreflectivity readings were 77 and 110 mcd/m^2/lx for the experimental and control markings, respectively. Due to similar performance along other test site locations, 3M discontinued manufacturing the product. Based upon its poor performance and discontinuation of the product, the marking will not be added to the Vermont Agency of Transportation's Approved Products List.

17. Key Words	18. Distribution Statement
Traffic marking tape polyurea	No restrictions

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. Pages	22. Price
Unclassified	Unclassified	15	

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1. INTRODUCTION

It has become common practice by the Vermont Agency of Transportation to recess polyurea markings on interstate rehabilitation projects. Recessing includes the removal of a small portion of the surface of the wearing course prior to the application of permanent markings. While studies have shown that recessing successfully extends the service life of traffic markings by protecting them from wear, there have been several concerns about the effectiveness of these markings under wet conditions. During rain events, a film of water collects over the marking materials causing a change in the indices of refraction between the optical elements and surrounding medium thereby reducing retroreflective properties, or luminance. Feedback from drivers confirms the issue as they report difficultly seeing the marking at night during rain events. As pavement markings provide an important means of communication for all roadway users, they must be capable of conveying information during inclement weather. To address this concern, pavement marking manufacturers have developed innovative traffic markings with wet reflective properties. This attribute is available in several types of traffic markings including durable pavement marking tapes.

Pavement marking tapes reportedly offer several advantages over other liquid applied traffic markings such as thermoplastic and polyurea. Marking tapes are manufactured under controlled conditions from a blend of polymers and reinforced materials which in theory should make the substrate more consistent and resistant to wear. Other features including glass beads and a pressure sensitive adhesive are also infused during the manufacturing process. In theory this should ensure uniform retroreflectivity and superior bonding surface. A recent statewide investigation of various pavement markings found a positive correlation between winter maintenance practices and marking decay due to shearing effects produced by plow operations. If recessed, durable tapes should be less vulnerable to winter maintenance practices.

In an effort to analyze the effectiveness of newly developed pavement marking tape with wet night properties, the Agency recessed "3M Stamark High Performance Wet Reflective Tape Series 380WR ES" on a portion of the Richmond – South Burlington project, IM 089-2(39). The following final report assessed the overall performance of these markings in terms of durability and retroreflectivity. This report also contains information related to the experimental method of placement and summarizes all surveillance and testing methods, data collection results and associated findings.

2. PROJECT DETAILS

In association with a federally approved work plan, WP 2008-3 (*1*), the 3M All Weather Permanent Tape was to be applied to a portion the Richmond – South Burlington project, IM 089-2(39), located along I-89 between mile marker (MM) 78.990 and MM 87.397. However, the roll of permanent marking tape was not available for this project. Therefore, the markings were placed on the southbound portion of the South Burlington – Colchester project, IM 089-3(60), located along I-89 between mile marker (MM) 87.770 to MM 91.880. According to the project plans, work to be performed included cold

planing, resurfacing with a leveling course and wearing course, new pavement markings, new signs, guardrail improvements, drainage improvement and other incidental items. The average annual daily traffic (AADT) is approximately 24,000 along the southbound interstate barrel at this location (16,000 travel and 8,000 passing lanes),a high AADT for the state of Vermont.

The prime contractor for the project, Pike Industries Inc., was responsible for all paving activities, and the subcontractor, L&D of Berlin, VT, was responsible for all pavement markings. As specified under the original contract plan, polyurea markings were to be applied throughout the limits of the project. However, the Materials and Research Section was approached by representatives from 3M of St. Paul, Minnesota regarding a new traffic marking tape with wet night properties and offered to supply the subcontractor a 300' roll of 6" 3M All Weather Permanent Tape at no additional cost. With agreement from Agency personnel, Pike Industries and L&D, the marking tape was placed as 30 center skip lines, each 10 feet in length.

3. PRODUCT DETAILS

According to the manufacturer (*2*), 3M Series 380WR ES is durable, conformable, patterned pavement marking tape which provides high retroreflectivity under both wet and dry conditions using abrasion-resistant microcrystalline ceramic beads that are bonded in a highly durable polyurethane topcoat. Reportedly, it meets or exceeds ASTM D 4505, "Standard Specification for Preformed Retroreflective Pavement Marking Tape for Extended Service Life" (*3*). According to this specification, preformed retroreflective pavement marking tape will provide a service life normally greater than one year on pavement surfaces having a daily traffic count equal to or less than 15,000 ADT per lane. The nominal thickness of the tape is 65 mils. The tape has an initial minimum skid resistance of 45 BPN (British Pendulum Number) when tested according to ASTM E 303-83, "Test Method for Measuring Surface Frictional Properties Using the Bridge Pendulum Tester" (*4*). As of the time of this report, the manufacturer had not established maximum roughness criteria for the application surface. Supposedly, it offers "Extended Season" application due to an improved pressure sensitive adhesive which does not require 3M Surface Prep Adhesive P-50 prior to application, if applied during the application season as outlined in 3M Climate Guide; it reportedly can be applied in temperatures down to 40ºF for both air and surface temperature, a common minimum application temperature for tape products. Typical applications include lane lines, edge lines, channelizing lines, gore markings, symbols, and legends. Reported average minimum retroreflectivity values immediately following application are 500 and 300 mcd/m^2/lx for the white and yellow markings in a dry condition, respectively. In a wet condition, reported average minimum retroreflectivity values immediately following application are 250 and 200 mcd/m^2/lx for the white and yellow markings, respectively.

According to product literature, the required depth for recessing the tape is 100 ± 10 mils at a width a least one inch greater than the width of the tape. Once grooving is complete, application instructions specify for the grooved area to be thoroughly cleaned with an air compressor with a minimum 185 cubic feet per minute (CFM) of air flow and 90 pounds per square inch (psi) of air pressure prior to applying the tape marking.

The control pavement marking for this project was a polyurea pavement marking material known as "3M Stamark Liquid Pavement Marking (LPM) 1200. The series 1200 markings consist of a durable, sprayable, polyurea binder that hardens rapidly after application, and can be used for long lines (center, edge, and skip), channelizing lines, and gore markings. According to the product data sheets it is initially three times brighter than conventional markings and incorporates a new highly reflective element made of microcrystalline ceramic beads. These elements are much larger than conventional glass beads. The product dries quickly, in 2 to 3 minutes, which is much faster than paints or epoxies. LPM 1200 reportedly provides excellent adhesion on both asphalt and Portland cement concrete. Like the experimental tape, it also allows for use within an extended striping season, down to 40°F in accordance with the product literature.

4. RETROREFLECTIVITY REQUIREMENTS

According to the project special provisions, Section 646, the minimum retroreflectivity requirement for the white and yellow traffic markings are 500 and 400 mcd/m^2/lx, respectively. However, as shown in the Material section above, these markings may be unable to meet this minimum standard. Therefore, this requirement was revised for this experimental placement to reference FHWA's minimum recommended retroreflectivity of 150 and 100 mcd/m^2/lx for the white and yellow pavement markings, respectively for the specified experimental markings and associated application locations only.

5. INSTALLATION

Bituminous pavement (Superpave Type IIIS wearing course) was placed on August 20th along the travel lane and August 22nd, 2008 along the passing lane at the location of the experimental marking. Recessing for pavement markings was performed on Thursday, October 23rd, 2008. The newly applied bituminous pavement was ground to a depth between 90 and 100 mils at an 8 inch width within the experimental test section. Subsequent application of the tape was completed on Tuesday, October 23rd, 2008, between 7 and 9 PM. Unfortunately Research personnel were not onsite. As such, it is unknown if the recessed areas were properly cleaned. According to the project notes, the temperature at the time of installation was approximately 35 to 40°F. The temperature reported by Weatherunderground.com (5) was between 32 and 38°F with no precipitation. This evidence suggests that the Agency's weather limitations were not achieved per the project specifications as at the time of application the ambient air temperature was less than 50°F. To improve adhesion, 3M Stamark Surface Preparation Adhesive P-50 was used as a primer and placed into the recesses with a primer cart prior to tape installation. It is important to note that in accordance with the product instructions, a minimum air temperature of 40°F was required. Once the primer was dry, the tape was placed in the grooves by hand and then rolled with a tamper cart. A total of 29 skip lines were applied within the southbound lane of I-89 between MM 88.502 and MM 88.833 as shown in Figure 1.

During the initial site visit conducted on Friday, October 31st, 2008, some portions of the tape did not appear to be adhered properly, as several corners could easily be pulled up

with minimal hand force as shown in Figure 2. It is unknown if this was the result of low temperatures during application, improper surface preparation, or some other factor.

Figure 1. Overview of the 3M tape on I-89, southbound.

Figure 2. Ease of pull-up of the installed 3M tape.

The LPM 1200 skip line markings were placed on the remainder of the project limits, from 87.770 to MM 91.880. Grooving for the control LPM 1200 material to a depth of roughly 32 mils was performed on the same date as the grooving for the tape. This recess depth, while in compliance with the Agency's specification, varies from the manufacturer's recommendation of 40 mils, which may result in decreased wear resistance. The LMP 1200 traffic markings were placed in the evening of Friday, October 26th, 2008 at the recommended thickness of 22 to 25 mils. According to Weatherunderground.com, temperatures during this timeframe were steady around 53°F.

6. SURVEILANCE AND TESTING

Two test sites were established throughout the length of the project in order to collect retroreflectivity readings in accordance with ASTM E 1710-97, "Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer" (*6*), and durability, in accordance with ASTM D 913-03, "Evaluating Degree of Resistance to Wear of Traffic Paint" (*7*). Test Site 1 consisted of all permanent tape markings. Test Site 2 consisted of five LPM 1200 skip lines immediately up and downstation of the experimental tape.

Retroreflectivity readings and visual assessments were collected utilizing a LTL 2000 retroreflectometer employing 30 meter geometry. All retroreflectivity measurements were taken at the center of each skip line. Photographic documentation was also gathered at individual test site locations during each field visit. Readings were recorded onto the appropriate field forms and then compiled into a dedicated spreadsheet. The initial site visit was conducted on October 31st, 2008, eight and five days following installation for the tape and polyurea traffic markings, respectively. All pavement markings were found to be intact as shown in Figures 3 and 4. A summary of initial average retroreflectivity readings is provided in Table 2 along with all averaged values for the duration of the evaluation. Values are averaged over all readings per test site. Please note that all of the experimental and control markings were found to be in compliance with ASTM 6359, "Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments" (*8*), which requires a minimum retroreflectivity of 250 mcd/m^2/lx for white markings within 14 days of application. As stated previously, one of the reported unique benefits and characteristics of the tape marking is wet night properties. Unfortunately, this could not be assessed quantitatively during this study, as a special retroreflectometer is required to test wet reflectivity, which was not available for this evaluation.

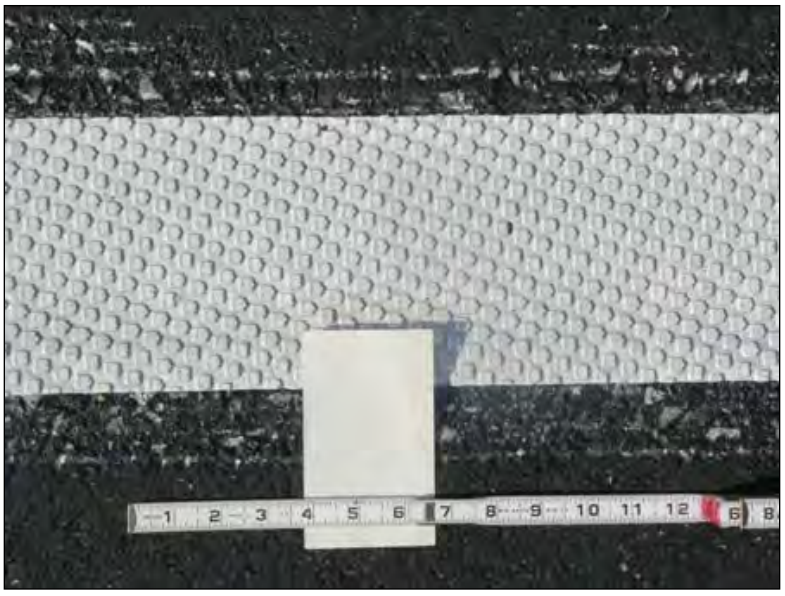

Figure 3. Appearance of the 3M Series 380WR ES tape eight days post-installation.

Figure 4. Appearance of the 3M LPM 1200 polyurea five days post-installation.

In addition to verifying initial retroreflectivity compliance with ASTM D 6359, all markings were monitored for performance over time. The service lives of pavement markings were used to compare durability and degradation rates to a predefined benchmark in order to evaluate and determine life cycle costs. To date, the Federal Highway Administration (FHWA) and other federal and state authorities have not established a minimum requirement for retroreflectivity of pavement markings. However, FHWA has compiled recommended retroreflectivity guidelines for white and yellow pavement markings for different classes of roads as shown in Table 1. As I- 89 is classified as a freeway with a posted speed limit of 55 mph, the recommended minimum retroreflectivity for white markings is 150 mcd/m^2/lx.

Table 1. Recommended minimum values for retroreflectivity from FHWA.

1998 FHWA Research-Recommended Pavement Marking Values			
Type	**Non-Frwy**	**Non-Frwy**	**Freeway**
Option 1	<= 40 mph	>= 45 mph	>= 55 mph
Option 2	<= 40 mph	>= 45 mph	>= 60 mph, >10K ADT
Option 3	<= 40 mph	45-55 mph	>= 60 mph
White	85	100	150
Yellow	55	65	100

6.1. Retroreflectivity

Table 2, as shown below, contains a summary of average reflectance for the experimental and control pavement markings. Please note that any readings below 250 mcd/m^2/lx within 14 days of application or 150 mcd/m^2/lx for the duration of the assessment are highlighted in blue and red font, respectively. Individual readings from each data collection event are provided in Appendix A.

Table 2. Retroreflectivity averages for all markings in the test area at the various site visit dates. Readings in mcd/m^2/lx.

Retroreflectivity Summary I-89 South Burlington White Skip Lines						
	Series 380WR ES Tape			LPM 1200		
Date	Days Since Application	Avg. Retro Reading	Std. Dev.	Days Since Application	Avg. Retro Reading	Std. Dev.
10/31/2008	8	401	51	5	698	96
5/19/2009	208	**77**	**8**	205	**110**	**17**
6/29/2009	249	**78**	**5**	246	**108**	**16**
9/16/2009	328	**73**	**7**	325	**106**	**17**

Red = below minimum FHWA recommendation (for 55 mph)

As stated previously, initial averaged retroreflectivity values for both products were well above the required 250 mcd/lx/m^2. Control marking retroreflectivity was found to be 74% higher as compared to the experimental tape which was to be expected given reported initial retroreflectivities from the manufacturer. The averaged retroreflectivity values for both marking types fell dramatically during the first winter season. Unfortunately, measurements were unable to be performed during winter months due to weather and traffic concerns. Following the winter season all readings for both marking types had fallen to well below the FHWA recommended minimum of 150 mcd/lx/m^2. The variability of both marking data sets were fairly consistent, with the control markings showing approximately twice the variability (with respect to standard deviations) as compared to the experimental markings. It should be considered, however, that there were 10 control markings as compared to 29 experimental markings. However, even with the standard deviations taken into account, average marking retroreflectivities were significantly below the recommended minimums. This is almost certainly due to the roadway characteristics with respect to high traffic volume and winter maintenance practices. As the ADT per lane is slightly greater or less than 15,000 as referenced in ASTM D 4505-05, a minimum service life of twelve months was anticipated for the permanent tape markings. However, this was not achieved. As of the final site visit, control marking retroreflectivity did retain 45% higher values than that of the experimental tape. The intended study period of three years was shortened to one year due to continued low retroreflectivity levels and discontinuation of the product.

6.2 Appearance

Another aspect pavement marking durability is the appearance of the line. Over time pavement markings can fade, crack, and pit leaving less remaining on the road surface. In the case of permanent tapes, a concern expressed by representatives of the Operations Division pertained to damage as a result of winter maintenance practices potentially resulting in a significant marking loss. This loss inhibits driver awareness, regardless of the retroreflectivity values, as the road boundaries begin to disappear. Wear was recorded at each site visit with a number between 0 and 10, 0 representing a line that is no longer visible and a 10 representing a line in perfect condition. Appearance ratings were

visually averaged over the entire test site for each marking type. A summary of the appearance of the lines over time is represented by Table 3.

Table 3. Durability values for all markings in the test area at the various site visit dates.

Durability Summary I-89 South Burlington White Skip Lines				
	Series 380WR ES Tape		LPM 1200	
Date	Days Since Application	Avg. Durability Reading	Days Since Application	Avg. Durability Reading
10/31/2008	8	10	5	10
5/19/2009	208	9	205	9
6/29/2009	249	7	246	7
9/16/2009	328	7	325	7

The values in the table indicate that the appearance and durability of all markings degraded at equal rates, with both markings receiving identical ratings at each site visit. Appearance ratings are comparable to other types of surface applied markings evaluated during the same time period. It was expected that the recessing of the markings would have a more profound effect on maintaining the appearance of the lines than it did, however this stretch of roadway receives the highest AADT in the state. Figures 5 and 6 below show the condition of the markings during the September 16th, 2009 site visit at eleven months of age. Cracking in the tape can be seen in numerous locations, along with general wear throughout. The LPM 1200 markings are noticeably duller as compared to Figure 4. While not visible in the photograph, a severe loss of glass and ceramic beads were noted.

Figure 5. Appearance of the 3M Series 380WR ES tape 328 days post-installation.

Figure 6. Appearance of the 3M LPM 1200 polyurea 325 days post-installation.

6.3 Service Life

Exact service life estimates for pavement marking could not be determined due to the extent of time between data collection events. Therefore, a scatter plot of the data was generated in order to establish the approximate amount of elapsed time before retroreflectivity values fell below 150 mcd/m^2/lx as shown in Figure 7.

The graphical representations clearly display a strong positive correlation between winter maintenance practices and pavement marking decay. As a point of reference, January 1, 2009 fell on day 69 and 72 on the plot for experimental and control markings, respectively,. Following the winter season, the traffic markings for both products maintained virtually the same retroreflectivity values for the remainder of the study period. The average retroreflectivity values for the 3M Series 380WR ES and LPM 1200 were below FHWA recommended minimums roughly 155 and 186 days following construction, respectively.

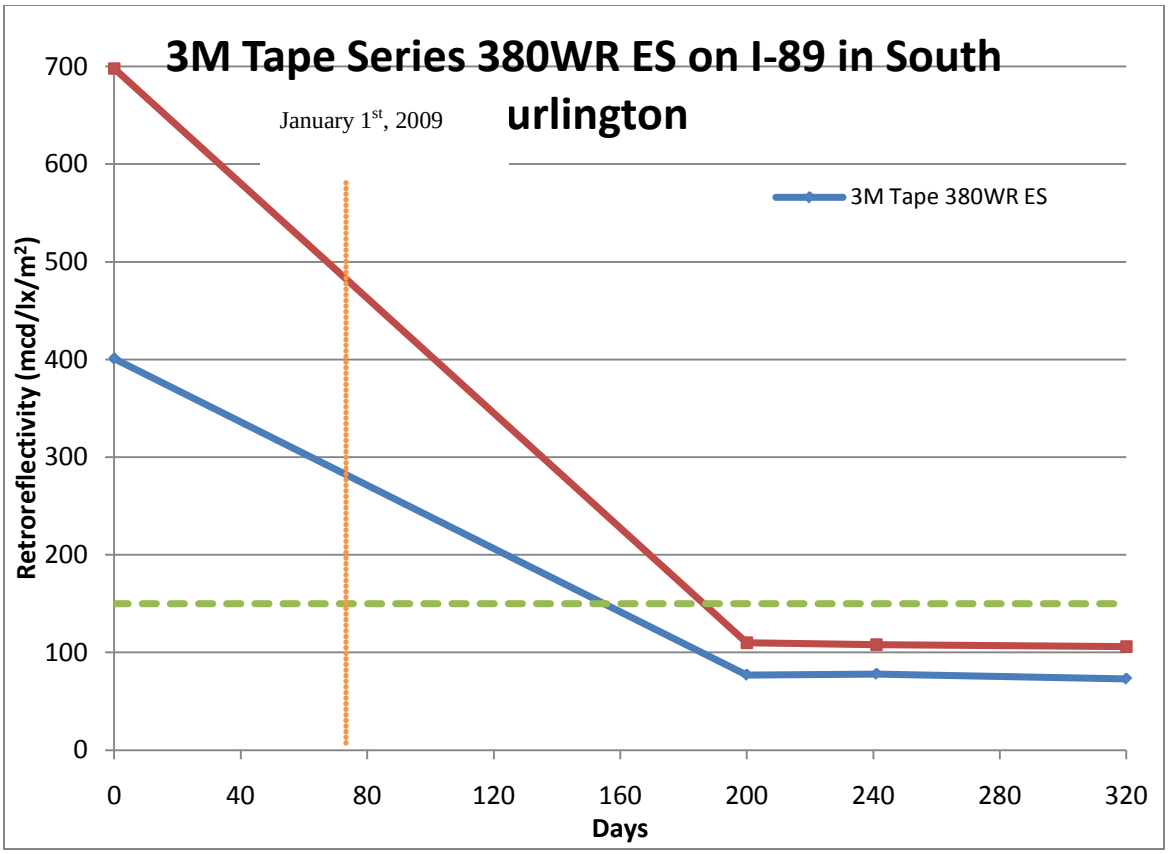

Figure 7. Plot displaying retroreflectivity values versus time for the two marking types.

6.4. Cost Analysis

All costs for application and marking materials were paid for as part of the construction project. 3M supplied the subcontractor a 300' roll of 6" 3M All Weather Permanent Tape at no additional cost. This material was distributed between the 29 skip lines.

The reported cost of 3M Stamark High Performance Wet Reflective Tape Series 380WR ES is $4.25 per square foot. This is equivalent to $2.13/LF for a 6" wide long line. The cost for 3M Stamark (LPM) Series 1200 that meets or exceeds the Agency's minimum initial retroreflectivity requirements is $65 per gallon for the marking substrate, $0.012/LF for glass beads and $0.058/LF for elements, for a total cost of $0.49/LF for a 6" wide long line. According to L&D Traffic Markings Inc. the total cost to apply LPM 1200 polyurea (material, labor, and grooving) is roughly $1.25 per linear foot, while for the 380 WR ES tape it is $4.20 per linear foot. Therefore, the total cost for the traffic marking tape is approximately 3.35 times greater than the LPM 1200 markings. Table 4 provides a cost comparison between the wet reflective tape and LPM 1200 versus the documented service life (or time until retroreflectivity values fell below FHWA recommended minimums). Overall, 380 WR ES was much more expensive, given its shorter service life and higher cost, equating to roughly four times greater cost than the LPM 1200 polyurea.

Table 4. Cost analysis summary for both marking types.

Richmond – South Burlington Project Material Cost Comparison[1]						
Material	**Service Life (Months)**	**Material Cost ($/LF)**	**Labor and Equip. Cost ($/LF)**	**Grooving Cost ($/LF)**	**Total Cost ($/LF)**	**Cost per Month ($/LF)**
380 WR ES	5.1	2.13	1.62	0.55	4.20	0.82
LPM 1200	6.1	0.49	0.41	0.35	1.25	0.20

Another methodology to compare the cost effectiveness of a marking material is to determine its net benefit to the user over its lifespan with consideration to increased retroreflectivity and older drivers. A study conducted by the University of North Carolina at Charlotte concluded "that nighttime luminance levels provided by pavement markings that may be adequate for younger drivers may be less than adequate for older drivers" (*9*). Therefore, rather than examining the amount of time until retroreflectivity levels fall below a minimum recommended level, the following assessment accounts for the retroreflectivity readings over time above minimum recommended levels as a net benefit. The net benefits are calculated by a determination of the area between the averaged retroreflectivity lines above the FHWA recommended minimum retroreflectivity in Figure 7.

Based upon the service lives of the markings and their recorded retroreflectivity values, the net benefits of the materials and the benefit per initial cost per foot are summarized in Table 5.

Table 5. Benefit analysis summary for both marking types.

Material	Benefit (mcd/lx/m^2*days)	Benefit per Cost/Foot
Stamark Series 380WR ES Tape	31,094	7,403
LPM 1200 Polyurea	64,905	51,924

As shown in Table 5, the LPM 1200 was approximately two times more beneficial to drivers as compared to the Stamark Series 380WR ES Tape under dry conditions. This also holds true with consideration to the cost/foot, where the control was a staggering 7 times more cost effective in this analysis.

It is important to note that the total benefit for a marking in Vermont is directly related to how early in the marking season a line is placed. If it is placed at the beginning of the season the public has the entire season to benefit from superior performance, while a marking placed towards the end of the season quickly degrades with the onset of the plowing season, making the marking far less beneficial with respect to safety and life cycle cost. Therefore, the benefit analysis can only be used as a qualitative comparison between two materials that have been placed on near identical dates.

[1] Cost values estimated based upon 3M and Traffic Markings Inc. provided data.

7. SUMMARY AND RECOMMENDATIONS

In an effort to enhance visibility during evening rain events, the Agency evaluated a traffic marking tape with "wet night" properties produced by 3M known as "3M Stamark High Performance Wet Reflective Tape Series 380WR ES." Long term performance was assessed in terms of retroreflectivity and wear. These characteristics were compared to a common application of a recessed polyurea. Service life estimates based upon retroreflectivity levels were derived using FHWA recommended minimum values.

The experimental tape and polyurea traffic markings were applied to a portion of the South Burlington – Colchester project, IM 089-3(60), located along I-89 by personnel from L&D Safety Markings. All of the experimental and control markings were found to be above the minimum required retroreflectivity for new markings during the initial site visits, with the control exhibiting 74% higher readings. The experimental tape and control polyurea traffic markings fell below the FHWA minimum recommended value of 150 mcd/lx/m^2 approximately 155 and 186 days following application, respectively. It is important to note that these values were estimated from a scatter plot of retroreflectivity values over time. This life cycle is likely largely influenced by winter maintenance practices and high traffic volume along this roadway segment. Unfortunately, the wet reflective properties of the permanent tape makings could not be assessed during this study as a special retroreflectometer is required to test wet reflectivity, which was not available for this evaluation.

A cost and benefit analysis showed that the cost of the Series 380WR ES tape is 3.3 times more expensive than the LPM 1200 with consideration to material, installation, and recessing, and 4 times more expensive based upon service life. A benefit analysis, which gives credit to a marking being well above FHWA minimum retroreflectivity values, concluded that the polyurea markings was 7 times more beneficial as compared to the experimental tape product.

It was hoped that these inlaid tape products would be less vulnerable to winter maintenance practices, resulting in higher maintained retroreflectivity values and greater durability over time. Unfortunately, with respect to retroreflectivity, this just was not the case. Even with the encouraging preliminary values, well above national standards, the markings' values plummeted very quickly after installation and continued degrading over the first winter, eventually falling below recommended minimums prior to the first post-winter site visit. The durability levels of the markings could be considered satisfactory, as many of the markings remain mostly intact and visible under lit conditions.

Subsequent to the installation of the tape, 3M determined that the product is insufficient for its intended purposes; therefore they have decided to cease manufacturing the product and have developed a substitute. The markings have since been replaced on the project following a year of service. Given continued low retroreflectivity levels and discontinuation of the product, this product will not be added to the Agency's Approved Products List.

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APPENDIX A

Table A6. All retroreflectivity results for experimental and control markings.

Reading #	Experimental			
SB 380 WR ES	SB White Skip			
	10/31/2008	5/19/2009	6/29/2009	9/16/2009
1	454	85	76	75
2	353	81	72	76
3	403	80	71	76
4	489	86	83	88
5	516	76	69	70
6	349	65	70	67
7	431	80	74	76
8	432	84	78	68
9	418	73	70	77
10	325	66	76	75
11	389	81	81	81
12	368	69	78	64
13	413	80	84	77
14	409	86	86	78
15	420	78	77	76
16	350	87	82	82
17	445	78	76	70
18	444	84	79	80
19	345	83	76	77
20	322	78	84	76
21	349	83	79	69
22	403	79	77	82
23	507	59	77	55
24	412	68	80	75
25	407	82	83	72
26	385	75	83	58
27	358	54	77	66
28	357	74	79	69
29	382	67	82	72
Average	**401.21**	**76.59**	**77.90**	**73.34**
Appearance	**10**	**9**	**7**	**7**
Std. Dev.	**50.98**	**8.40**	**4.59**	**7.12**
Reading #	**Control**			
Before Tape	**10/31/2008**	**5/19/2009**	**6/29/2009**	**9/16/2009**
1	796	116	114	103
2	717	113	113	101
3	713	124	131	111
4	795	125	123	117
5	847	131	120	129
After Tape	**10/31/2008**	**5/19/2009**	**6/29/2009**	**9/16/2009**
6	581	100	95	101
7	712	114	110	65
8	593	88	91	102
9	586	79	78	120
10	639	108	103	113
Average	**697.9**	**109.8**	**107.8**	**106.20**
Appearance	**10**	**9**	**7**	**7**
Std. Dev.	**95.88**	**16.57**	**16.14**	**17.24**

Numbers in red indicate readings that were below the FHWA recommended minimum of 150 mcd/lx/m^2 for a freeway.