Evaluation of ATM 400 Permanent Durable Tape
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16. Abstract

The following report outlines the final observations with regards to the application of two experimental heavy and moderate grade permanent marking tapes, known as ATM 400 and ATM 300, respectively, in association with stop bars, crosswalks and longitudinal markings. In addition the report summarizes field performance over time in terms of durability and retroreflectivity.

Five test sites were established at the intersections of VT 15, VT 128, and Towers Rd. in Essex and monitored for a period of two years. Overall, there are several important considerations for the placement of the ATM 300 and 400 permanent tapes. For example, the tapes must be inlaid into bituminous concrete during compaction. This may cause delays in the laydown process. In addition, retroreflectivity values degraded quickly with the onset of traffic and winter maintenance activities. Therefore, the use of these products is only recommended for smaller scale projects with adequate lighting during evening hours, such as an intersection.

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1. Introduction

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. Unlike surface applications for liquid traffic markings, pavement marking tapes when used as a final durable marking, must be inlaid in the bituminous pavement during final compaction. 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 properly inlaid, durable tapes should be less vulnerable to winter maintenance practices as the surface of the marking should be level to the surface of the pavement.

Pavement markings tapes, like all other products, do have their drawbacks. A recent investigation conducted by VTrans found that the inlay application method requires significant coordination between the paving operator and marking applicator which typically lengthens the time for construction. In addition, tapes are generally more expensive than other marking alternatives. Finally, while the inlay method should protect the markings against shearing and tearing, representatives from the Operations Division have expressed concern over a common failure mechanism typically induced by winter maintenance activities. Shearing effects produced by the impact of plow blades will often raise or tear the marking material. Given the continuity of the product, it is then very susceptible to a global versus a localized failure.

Marking tapes are often offered in different grades or series. Advanced Traffic Marking Inc. (ATM) provides a moderate and heavy grade tape. In this case, the composition of the two markings tapes is identical with the exception of the thickness and recommended applications. The moderate grade tape is 60 mils and recommended for longitudinal and transverse application in moderate traffic areas. The heavy grade tape is 90 mils and recommended for longitudinal and transverse application in high traffic areas.

The following report outlines the final observations with regards to the application of two experimental heavy and moderate grade permanent marking tapes, known as ATM 400 and ATM 300, respectively, in association with stop bars, crosswalks and longitudinal markings. In addition the report summarizes field performance over time in terms of durability and retroreflectivity. Please note that no control, or standard marking materials, was applied in conjunction with this project.

2. Project Details

In association with a federally approved work plan, WP 2007-6, all pavement markings, including stops bars, crosswalks and longitudinal markings were applied to the Essex signal project, STPG SGNL (17), in the summer of 2007 located at the intersection of VT Route 15 and VT Route 128 at MM 5.34 in the town of Essex as shown in Figure 1 below. In accordance with the plans, this project included installing a new traffic signal system, upgrading pedestrian crossings, new signs, paving, and pavement markings to increase capacity and improve safety. The average annual daily traffic (AADT) in 2006 was 15,800 for VT 15, a high AADT for a Vermont Route.

Figure 1. Project location at the intersection of VT 15, VT 128, and Towers Rd.

The prime contractor, Pike Industries Inc., was responsible for all paving activities, and the subcontractor was Scott's Line Striping, was responsible for all pavement markings. As specified under the original contract plan, thermoplastic was to be applied throughout the limits of the project. However, the Resident Engineer (RE), Greg Wilcox, was approached by Scott's Line Striping, regarding the installation of permanent marking tape on the grounds that permanent tapes have proven to be more durable in high AADT locations. Once agreed upon by the Resident and project manager, Josh Schultz, the contract was modified for the application of permanent tape. ATM 400 tape was utilized for the letters and symbols as well as some of the stop bars and crosswalks, while ATM 300 tape was placed for the longitudinal markings and the remaining stop bars and crosswalks.

3. Product Details

According to the manufacturer, Advanced Traffic Markings, Inc. from Roanoke Rapids, NC, ATM 400 Permanent Durable Tape is lead free and environmentally safe. Reportedly, it meets or exceeds ASTM D 4505, "Standard Specification for Preformed Retroreflective Pavement Marking Tape for Extended Service Life" [1] and is marketed as a tape consisting of high quality polymeric materials, pigments, and glass beads to assure long term retroreflectivity. It's pre-applied, pressure sensitive adhesive minimizes tape movement in hot and cold climates. The ATM adhesive system is claimed to extend the application season as well. When applied in accordance with the manufacturer's recommendations it adheres to either asphalt or Portland cement roadway surfaces and should provide a minimum service period of 24 months under a moderate to heavy traffic volume.

ATM 400 Permanent Durable Tape is the manufacturer's "heavy grade" permanent tape (as opposed to the moderate grade 300 series). The tape is recommended for use in both longitudinal and transverse applications. It is a minimum of 90 mils (2.29 mm) thick to resist wear and provide extended life. The tape offers optional anti-skid particles and reportedly has an initial minimum skid resistance of 55 British Pendulum Number (BPN) when tested according to ASTM E 303-83, "Test Method for Measuring Surface Frictional Properties Using the Bridge Pendulum Tester" [2]. According to the manufacturer, the inlay method requires pavement temperatures between 120°F to 175°F. ATM 300 tape is comprised of the same components, however it varies from the ATM 400 tape in that is a minimum of 60 mils thick with an anticipated minimum service life of 16 months.

4. Installation

Application of the ATM 400 and ATM 300 permanent tapes was completed on Saturday, August 4th, 2007. According to www.weatherunderground.com, the mean temperature was 72°F with an average humidity of 57% and no precipitation. As stated previously, Scott's Line Striping was the subcontractor on the project. In addition to the contractor, the project resident was also onsite to examine the application of the permanent tape.

Scott's Line striping monitored the temperature of the HMA following initial compaction efforts to determine the appropriate time for the placement of the permanent marking tape. With respect to the longitudinal markings, once the pavement cooled to acceptable temperatures, the striping company offset the placement of the centerline marking from the pavement joint so that the marking material would not be applied directly over the joint. After the centerline was established, both white edge lines were marked in accordance with the plans. Then a handcart was used to apply the marking tape. The handcart was equipped with a special cutting blade providing a nice even finish. Finally, the final pavement rolling pattern typically utilized for compaction of the HMA was also used to inlay the tape into place. Please note that this process does require special attention to sequencing. If utilized for a great length, this process may affect the rate of pavement placement and finishing.

According to the Resident Engineer's daily reports "this method worked well although there were some areas that seemed to be applied at too hot a temperature as the tape stretched and then when it cooled it pulled the mix apart which left a void." Figure 2, displayed below, depicts a spot where shrinkage (or void) occurred during application. As stated previously, the manufacturers recommended surface temperature for application is 120°F to 175°F. Theoretically, this shrinkage should be minimized by applying the tape at proper pavement temperature. However according to the RE, Greg Wilcox, all temperature readings were well within the manufacturer's specifications (125°F to 163°F). According to correspondence, Greg Wilcox wrote "my observations lead me to conclude that the tape could/should be laid down at even lower temperatures, say nothing above 140°F. Also the contractor should have a plan to fix areas that stretched and then cooled." [3] Interestingly, application literature states, "if tape distorts or wrinkles, surface temperature may be too hot or roller speed may be too fast."

Appendix A contains a summary of project locations and pavement application temperatures at each test site along with other pertinent information. The average pavement temperature at the time of installation for ATM 400 tape was calculated to be 138°F, while the average temperature for ATM 300 tape was slightly higher at 144°F. As a final consideration, the daily report also states that "the in-laid tape added to the traffic delays because the crew was laying out and working areas that could be used for traffic."

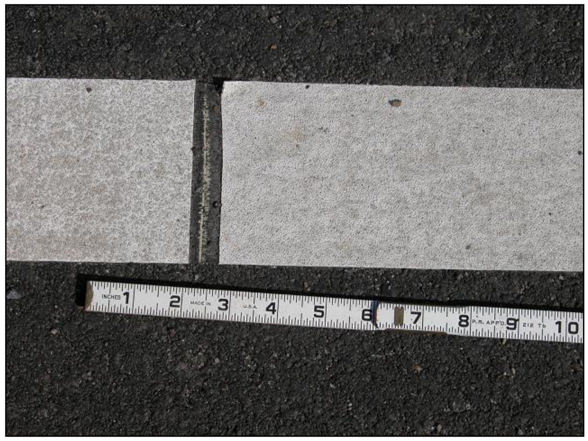

Figure 2. Void evidenced between tape segments.

5. Surveillance and Testing

Five 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" [4], and durability, in accordance with ASTM D 913-03, "Evaluating Degree of Resistance to Wear of Traffic Paint" [5]. Test sites one through three and four through five were identified within areas containing ATM 400 and ATM 300 permanent tapes, respectively. Test sites one, two and four were located along crosswalks with readings collected in the center of every other marking. Test site three was positioned across the stop bar at the end of the right turn only lane along VT Route 15 with readings collected in two foot increments. Test site five was established along the southeast longitudinal white edge line and consisted of a total length of 40 feet with data collection conducted at 10 foot intervals starting from the beginning of the test site. Please see Appendix B for a detailed map of all test sites. Each data collection location was identified with white marking paint in order to ensure that all readings would be collected from the same location. It is important to note that TS 4 along Towers Road, comprised of ATM 300 tape, is subjected to far less traffic as compared to the other test sites. The test site locations and estimated 2009 AADTs for each of the road sections is provided in Table 1.

Table 1. Locations of the five test sites.

Test Site Properties			
Test Site ID:	**Tape Grade:**	**Location:**	**AADT:**
TS 1	ATM 400	VT 15 - East Crosswalk	12,500
TS 2	ATM 400	VT 15 - West Crosswalk	16,500
TS 3	ATM 400	VT 15 - West Stop Bar	16,500
TS 4	ATM 300	Towers Road - Crosswalk	1,600
TS 5	ATM 300	VT 15 - East Edgeline	12,500

Retroreflectivity readings and visual assessments were collected utilizing an LTL 2000 retroreflectometer which employs 30 meter geometry. Photographic documentation was also gathered at individual test site locations during each field visit. All retroreflectivity and durability readings were recorded onto the appropriate field forms and then compiled into a dedicated spreadsheet.

5.1 Initial Performance

An initial site visit was conducted on August 10th and August 15th,6 and 11 days following application, respectively. All pavement markings were found to be intact. A summary of initial retroreflectivity readings is provided within Table 2 below. Please note that all of the experimental markings were found to be in compliance with ASTM 6359, "Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments" [6] which requires a minimum retroreflectivity of 250 mcd/m^2/lx for white markings within 14 days of application.

Table 2. Initial performance comparison

Retroreflectivity Summary (all readings in mcd/m^2/lux)								
	ATM 400					ATM 300		
Date	Days Elapsed	TS 1 Crosswalk	TS 2 Crosswalk	TS 3 Stop Bar	Average	TS 4 Crosswalk	TS 5 Edgeline	Average
8/10/2007	6	1075	902	1118	1032	727	705	716
8/15/2007	11	1057	819	997	958	669	640	655

The average initial retroreflectivity of the ATM 300 and 400 markings was 716 and 1032 mcd/m^2/lx, respectively. Although slightly below the manufacturer's minimum reported reflectance of 800 mcd/m^2/lx for the ATM 300 markings, the initial values are impressive. For comparative purposes, a statewide examination of various pavement markings found that white thermoplastic markings display an initial reflectance of approximately 500 mcd/m^2/lx [7].

5.2 Long Term Performance

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, or 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 marking for different classes of roads as shown in Table 3. The posted speed limits along the roadway segments of VT 15 and Towers Rd. in Essex are below 40 and classified as "Non-Freeway." Therefore, a minimum retroreflectivity of 85 mcd/m^2/lx is recommended.

Table 3. FHWA recommendations

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

Tables 4, as shown below, contain a summary of average reflectance for each of the ATM 400 and 300 permanent tapes, respectively. Please note that any readings below the recommended value are noted in red font. The data tables summarize the average retroreflectivity reading for each test site along with an overall average for each data collection event.

Table 4. Long term performance comparison

Retroreflectivity Summary (all readings in mcd/m^2/lux)								
	ATM 400					ATM 300		
Date	Days Elapsed	TS 1 Crosswalk	TS 2 Crosswalk	TS 3 Stop Bar	Average	TS 4 Crosswalk	TS 5 Edgeline	Average
8/30/2007	26	836	570	753	720	578	523	551
10/4/2007	61	664	446	415	508	431	419	425
11/19/2007	107	310	140	137	196	179	215	197
4/17/2008	257	**37**	**26**	**27**	**30**	**28**	**39**	**34**
9/25/2008	418	105	**35**	**32**	**57**	**30**	**33**	**32**
5/12/2009	647	**38**	**34**	**29**	**34**	**36**	**36**	**36**
7/28/2009	724	89	**38**	**27**	**51**	**30**	**43**	**37**

The averaged retroreflectivity values for both the ATM 400 and 300 fell consistently during the first four months of service. A more dramatic decrease in retroreflectivity values occurred during the first winter season, with all readings falling well below the FHWA recommended minimum of 85 mcd/m^2/lx. This is almost certainly due to snow plowing activities which readily shears glass beads from the surface of the tape substrate. The tape itself was also damaged in some areas following the winter season as is described in Section 5.2 below.

Retroreflectivity values of the ATM 400 markings were 44% higher on average than the 300 markings during initial data collection conducted on August 10th, 2007 and remained 28% higher on average until the winter season. After the first winter season, retroreflectivity levels were virtually identical for both marking types, except for some slight variability between data collection events. Readings collected from TS 1 on September 25th, 2008 and August 28th, 2009 yielded much higher retroreflectivity values, which directly resulted in higher averaged values for ATM 400 as compared to ATM 300 during those dates; otherwise values would have been roughly equivalent.

ATM product representatives, following the first winter season, explained that with continued wear a second layer of glass beads would be exposed, thus raising the retroreflectivity values somewhat. Following two years of service this has not been observed, as retroreflectivity values have remained more or less constant following the first winter season.

5.3 Appearance of ATM 400 and 300

Another important aspect pavement marking durability is line appearance as the pavement marking substrate provides roadway delineation during daylight hours. Over time pavement markings can fade, crack, and pit leaving less substrate 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 loss of the markings. Any damage may reduce driver awareness, regardless of the retroreflectivity values, as the road boundaries begin to disappear. Therefore, marking appearance was examined during each site visit in accordance with ASTM D 913-03. Appearance was expressed 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. A summary of the appearance of the lines over time is represented in Table 5.

Table 5. Recorded appearance values on all test sites and their associated averages.

Date	Days Elapsed	ATM 400				ATM 300		
		TS 1 Crosswalk	TS 2 Crosswalk	TS 3 Stop Bar	Average	TS 4 Crosswalk	TS 5 Edgeline	Average
8/10/2007	6	10	10	10	10	10	10	10
8/15/2007	11	10	10	10	10	10	10	10
8/30/2007	26	10	10	10	10	10	10	10
10/4/2007	61	10	10	10	10	10	10	10
11/19/2007	107	10	10	10	10	10	10	10
4/17/2008	257	7	6	6	6.7	7	8	7.5
9/25/2008	418	7	6	6	6.7	6	8	7
5/12/2009	647	6	6	5	5.7	5	8	6.5
7/28/2009	724	6	6	5	5.7	3	8	5.5

The values in the table indicate that the appearance and wear rates of all markings degraded at similar rates the exception of a portion of the crosswalk within TS 4 (ATM 300 Tape). It is interesting to note that as of July 28th, 2009 the permanent tape markings of TS 4 displayed almost twice the wear as compared to the crosswalk markings of TS 1 and 2 (ATM 400 Tape). In accordance with data collected on July 28th, 2009, the ATM 400 markings were slightly more resistant to wear as compared to the ATM 300 markings on average. However, this trend was not consistent over the evaluation period. Supposedly, the ATM 400 tape should have been more durable due to the grade and greater mil thickness. However the readings collected from April 17th, 2008 through May 12th, 2009 do not support the manufacturer's claim as the wear readings of the crosswalk markings are roughly equivalent. However, these wear patterns are likely attributed to associated traffic characteristics, as the AADT within TS 1 and 2 (12,500 and 16,500, respectively) is far greater than TS 4 (1,600). And although some portion of the markings wore over time, no catastrophic failures were observed during the monitoring period. Figures 3 and 4 below show the progressive wear on test sites 1 and 3, respectively. The left hand image in each figure shows the initial appearance of the sites, the second at 8 months (following the first winter), and third at 19 months.

Figure 3. Progressive wear characteristics of test site 1, from left to right, at 0, 8, and 19 months post construction.

Figure 4. Progressive wear characteristics of test site 3, from left to right, at 0, 8, and 19 months post construction.

5.4 Service Life

Service life estimates for the white crosswalk markings could not be determined due to the large 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 85 mcd/m^2/lx, as shown in Figure 5. Please note that only white crosswalk markings are modeled for this analysis due to the inherent variability comparing various marking types.

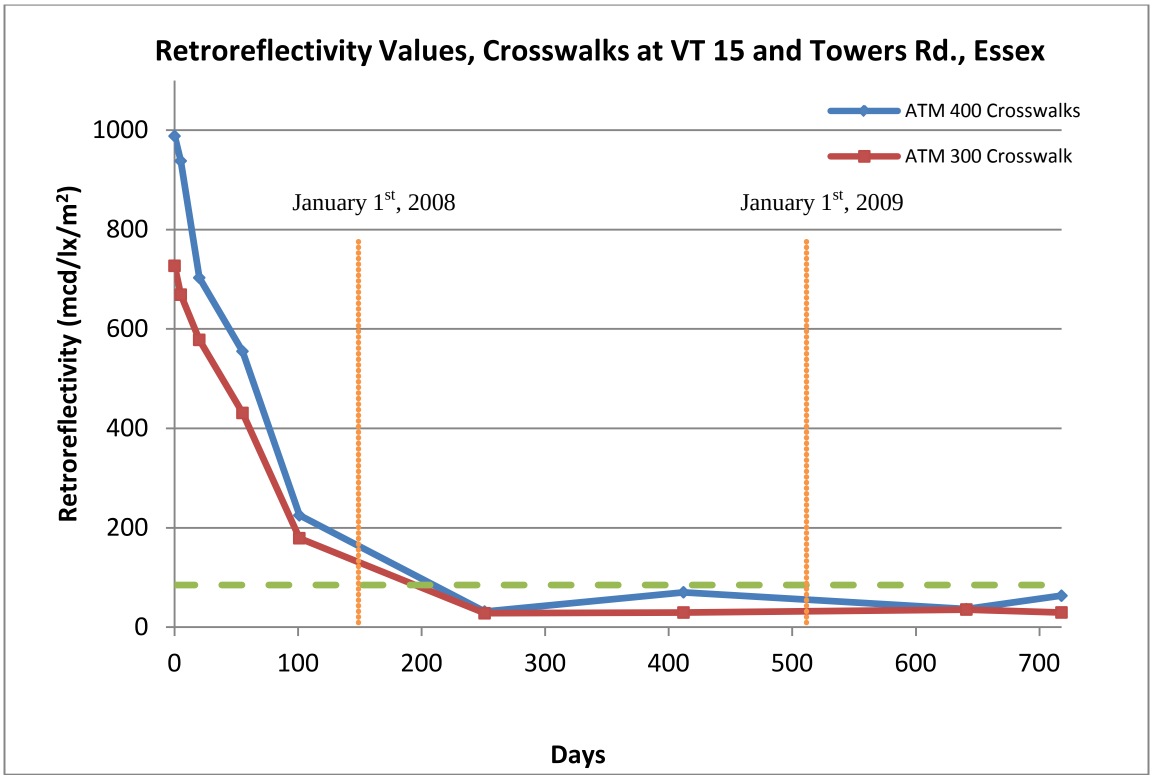

Figure 5. Plot of retroreflectivity values versus time for test sites comprised of crosswalks. Vertical orange lines indicate a date of January 1st, while green indicates the day when retroreflectivity values fell below the minimum.

The graphical representations clearly display a strong positive correlation between winter maintenance practices and pavement marking decay. The effects of the first winter season appear to result in the greatest decay over the monitoring period whereas the second winter season appears to have minimal impact on pavement marking retroreflectivity. It is likely that the majority of the bead loss occurred during the first winter season and any remaining beads were sufficiently embedded into the marking tape as to be protected from subsequent plowing events. In addition to a decrease in values during the winter, a very sharp decrease was also observed well before snow plowing began. In any case, the average retroreflectivity values for the crosswalk markings comprised of the ATM 300 and ATM 400 were below FHWA recommended minimums roughly 200 and 216 days following construction, respectively. These decay rates are likely largely influenced by traffic volumes along each roadway as markings along VT 15 (with a moderate AADT) were anticipated to wear more readily as compared to those along Towers Rd. (with a low AADT). Therefore under similar traffic conditions, the ATM 400 marking are expected to display a longer service life as compared to ATM 300.

5.5. NTPEP Test Deck

ATM 300 and 400 markings were assessed through the National Transportation Product Evaluation Program (NTPEP), a program intended to eliminate duplicative testing by member states. The markings were applied to a test deck in Pennsylvania on July 10th, 2008. In addition to the Pennsylvania test deck, the ATM 300 product was placed on a Mississippi test deck in 2006. However given the different climatic conditions, the results are not considered relevant to Vermont.

NTPEP test decks require the application of four beaded transverse lines, spanning the width of a travelled lane, per product [8]. The four transverse lines are applied to two separate areas allowing for a better statistical representation of the product. Transverse lines provide a comparison between lines that are heavily travelled by traffic (in the wheel paths) and areas with little to no traffic (near the centerline). Data from these test decks are recorded monthly, weather permitting. Retroreflectivity is assessed in the left wheel path and in close proximity to the centerline of the road. Readings are also collected with a 30 meter CEN geometry portable retroreflectometer in accordance with ASTM D 1710. Test deck locations are chosen on level, straight roadways, with no intersections and AADTs greater than 5,000. Preliminary results from the Pennsylvania test deck are presented in Table 6.

Table 6. First year retroreflectivity results from the 2008 Pennsylvania NTPEP test deck.

ATM 400 and 300 Retroreflectivity Readings from 2008 Pennsylvania NTPEP Test Deck					
Months	**Date**	**ATM 400**		**ATM 300**	
		Skip	**Left Wheel**	**Skip**	**Left Wheel**
Installation	7/10/2008				
0	7/28/2008	493	477	451	646
1	8/26/2008	405	186	480	339
2	9/30/2008	383	159	442	281
3	10/27/2008	323	151	424	241
9	4/28/2009	74	57	149	76
10	5/19/2009	95	55	160	67
11	7/9/2009	58	46	112	58
12	7/28/2009	79	45	125	55

Both the ATM 300 and 400 markings were installed on July 10th, 2008. Initial readings were collected 18 days following application which is greater than the allowable 14 day period per ASTM 6359. However initial readings were found to be greater than the 250 mcd/m^2/lx as required by this specification. Based on interpolation, comparable retroreflectivity readings at 18 days following application were found to be 847 and 606 mcd/m^2/lx for the ATM 400 and 300 readings within our study, respectively, representing a 74 and 10 percent increase on average. As corroborated by our observations, a sharp decrease in retroreflectivity values was documented within the heavily traveled areas (left wheel path). In addition, there was a significant loss of retroreflectivity values following the first winter season regardless of the collection location.

5.6. Cost Analysis

All costs for the application of the marking and marking materials were paid for as part of the construction project for a total longitudinal length of 0.124 miles (660 linear feet). Specifically, this was to include all white and yellow pavement markings, as well as stop bars, crosswalk markings, and lettering. The cost for the ATM 400 tape including materials and installation was as follows: $150 for the letters, $1320 for the stop bars, and $1560 for the crosswalks. Advanced Traffic Markings agreed to supply the state with 1900 LF of 4” durable white line, 650 LF of durable 4” yellow line, 75 LF of durable 24” wide stop bars, 190 LF of durable crosswalk markings with diagonal lines, and 22 durable letters and symbols, as shown within the quantity sheets of the project plans.

5.6.1 Life Cycle Cost Analysis

As of the summer of 2007, ATM 400 permanent marking tape cost approximately \$3.25/ft^2. This is equivalent to \$1.08/LF for a 4” wide long line application. The ATM 300 permanent marking tape cost roughly \$2.00/ft^2 which is equivalent to \$0.66/LF for a 4” wide line. For comparison, thermoplastic paint typically cost \$0.48/LF for a 4” wide line. Therefore, the material cost for the ATM 400 markings were approximately 64% greater as compared to the ATM 300 markings. Installation costs for ATM tapes, inlaid, are approximately \$3.00 per linear foot, while comparable thermoplastic markings cost around \$0.55 to install. Table 7 provides a cost comparison between the ATM 400 and 300 crosswalk markings.

Table 7. Service life and related cost comparison of ATM 300 versus ATM 400.

Essex Signal Project Material Cost Comparison					
Material	**Service Life (Months)**	**Material ($/LF)**	**Labor and Equipment ($/LF)**	**Total Cost ($/LF)**	**Cost/Month ($/LF)**
ATM 300	6.57	0.66	3.00	3.66	0.557
ATM 400	7.10	1.08	3.00	4.08	0.575

In accordance with the cost estimate provided in the table above, it appears that ATM 300 is very slightly more cost effective than the ATM 400 on cost per foot per service life in months.

5.6.2 Net Benefit Cost Analysis

Another methodology to compare the cost effectiveness of a marking material is to determine its net benefit to users 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 benefit is calculated by a summation of the area between the averaged retroreflectivity readings and FHWA recommended minimum in Figure 5, until readings fall below the minimum value.

Based upon the service lives of the markings derived from recorded retroreflectivity values, the net benefits of the materials and the benefit per total cost per foot are summarized in Table 8.

Table 8. Net benefit versus cost analysis of ATM 300 versus 400.

Essex Signal Project Net Benefit/Cost Analysis		
Material	**Benefit (mcd/lx/m2*days)**	**Benefit per Cost/Foot**
ATM 400	56,543	13,859
ATM 300	40,598	11,092

The ATM 400 crosswalk markings were found to be approximately 39% more beneficial to drivers than the ATM 300. Since this benefit favors ATM 400 and it only costs 11% more than ATM 300 installed, the ATM 400 has a better benefit per cost ratio, 25% greater than the ATM 300 (for the crosswalk test sections). Since, as stated earlier, the ATM 400 crosswalk markings were subject to far greater AADT; therefore it is very likely that the given identical circumstances the ATM 400 markings would have fared even better in this comparison.

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 construction season the public has the remainder of the summer and fall to benefit from superior performance. Conversely when applied at the end of the construction season, markings decay quickly with the onset of winter maintenance activities 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.

6. Summary and Recommendations

Two experimental permanent pavement marking tapes, known as ATM 400 and ATM 300, were applied to the Essex signal project, STPG SGNL (17) located at the intersection of VT Route 15 and VT Route 128 at MM 5.34 in the town of Essex on Saturday, August 4th by personnel from Scott's Line Striping. This process was somewhat labor intensive as compared to the installation of liquid pavement markings, such as thermoplastic and polyurea, and had to be accomplished in concert with the compaction of the hot mix asphalt. Remarks from the Project Resident noted extended traffic delays and concerns regarding application temperature in association with observed shrinkage. However, temporary markings were not needed in the process unlike most liquid marking applications which generally require a large portion of the project to be completed prior to application to reduce overall costs. No control, or standard marking material, was applied in conjunction with this project.

In addition to monitoring the application, five test sites were established throughout the length of the project for the collection of retroreflectivity and wear readings. All of the experimental tape markings were found to be well above the ASTM specified minimum required retroreflectivities for new markings during the initial site visits. Subsequent site visits were conducted on a periodic basis. Following the two year monitoring period, service life estimates were determined by calculating the amount of time elapsed between application and when the markings fell below FHWA minimum recommended retroreflectivity level of 85 mcd/m^2/lx for white non-freeway markings within a posted speed limit of 40 mph or less. The ATM 400 and 300 crosswalk markings fell below this threshold at approximately 216 and 200 days following application, respectively. The steep decay in retroreflectivity values is likely due to winter maintenance activities. In addition, the comparable decay rates are likely largely influenced by traffic volumes along each roadway as markings along VT 15 (with a moderate AADT) were anticipated to wear more readily as compared to those along Towers Rd. (with a low AADT). Therefore under similar traffic conditions, the ATM 400 marking are expected to display a longer service life as compared to ATM 300.

A cost and benefit analysis revealed that the cost of the ATM 400 product is 11% more expensive than ATM 300. A subsequent benefit analysis, which gives credit to a marking above FHWA minimum retroreflectivity values shows that the ATM 400 product exceeded that of the ATM 300 by 39%, and by 25% on a benefit per cost..

Overall, there are several important considerations for the specified placement of the ATM 300 and 400 permanent tapes. For example, the tapes must be inlaid into bituminous concrete during compaction. This may cause delays in the laydown process. In addition, retroreflectivity values degraded quickly with the onset of traffic and winter maintenance activities. Therefore, the use of these products is only recommended for smaller scale projects with adequate lighting during evening hours, such as an intersection. Other reports evaluating inlaid tapes and surface applied liquid markings should rebviewed to fully inform the reader.

References

[1] ASTM D 4505, “Standard Specification for Preformed Retroreflective Pavement Marking Tape for Extended Service Life,” ASTM International, West Conshohocken, PA, <www.astm.org>.

[2] ASTM E 303-83, “Test Method for Measuring Surface Frictional Properties Using the Bridge Pendulum Tester,” ASTM International, West Conshohocken, PA, <www.astm.org>.

[3] Vermont Agency of Transportation Resident Engineer Greg Wilcox, residing over STPG SGNL (17), construction daily comments and correspondence during tape installation, recorded September 14, 2007.

[4] ASTM E 1710-97, “Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer,” ASTM International, West Conshohocken, PA, <www.astm.org>.

[5] ASTM D 913-03, “Evaluating Degree of Resistance to Wear of Traffic Paint,” ASTM International, West Conshohocken, PA, <www.astm.org>.

[6] ASTM D 6359-99, “Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments,” ASTM International, West Conshohocken, PA, <www.astm.org>.

[7] Fitch, Jennifer, “Pavement Marking Durability, Statewide”, Final Report, State of Vermont Agency of Transportation, Materials and Research Section, February 2007.

[8] Project Work Plan for the Field and Laboratory Evaluation of Pavement Marking Materials, National Transportation Product Evaluation Program, August 2008.

[9] Graham, Johnny R., Harrold, Joseph K., King, L. Ellis, “Pavement Marking Retroreflectivity Requirements for Older Drivers”, Transportation Research Record, Volume 1529, pp. 65-70, 1996.

Appendix A

Type of Line	Pavement Temp (°F)	ATM Tape Series	Station
Symbol	138	400	280+13 Lt
Symbol	127	400	280+13 Rt
Letters	142	400	280+50 Lt
Letters	125	400	280+50 Rt
Symbol	135	400	280+86 Lt
Symbol	140	400	280+86 Rt
Stop Bar	133	400	280+99 Lt to CL
TS 3 Stop Bar	**140**	**400**	**281+19 CL to Rt**
TS 2 Crosswalk	**137**	**400**	**281+28 Lt to Rt**
TS 1 Crosswalk	**150**	**400**	**282+28 Rt to CL**
TS 1 Crosswalk	**137**	**400**	**282+28 CL to Lt**
Stop Bar	150	400	282+37 CL to Rt
Crosswalk	145	300	0+51 CL to Lt
Crosswalk	136	300	0+51 CL to Lt
Stop Bar	140	300	0+60 Lt
TS 4 Crosswalk	**163**	**300**	**10+44 CL to Lt**
TS 4 Crosswalk	**155**	**300**	**10+44 CL to Rt**
Stop Bar	132	300	10+63 CL to Lt
Double Yellow	135	300	279+50 to 281+00
Double Yellow	144 start, 156 end	300	282+36 to 284+00
Double Yellow	145	300	0+59 to 1+50
Double Yellow	137	300	10+64 to 11+50
TS 5 4" White Edge Line	**150 start, 135 end**	**300**	**279+50 Rt to 282+95 Rt**
4" White Edge Line	149	300	284+00 Lt to 1+50 Rt
4" White Edge Line	160	300	1+50 Lt to 11+50 Rt
4" White Edge Line	129	300	11+50 Lt to 279+50 Lt

Stations of 279+50 through 284+00 refer to Route 15
Stations of 10+00 through 11+50 refer to Towers Road
Stations of 0+00 through 1+50 refer to VT 128
Bold indicates retroreflectivity test sites

Table B1 – Pavement temperatures at time of all ATM tape installations

A complete list of all ATM tape installations for this project is provided in Table B1. The type and purpose of each tape placement is listed along with the exact stationing of each and the associated pavement temperatures at time of installation. Two entries have multiple temperatures listed, as these applications were done in multiple sections.

Appendix B

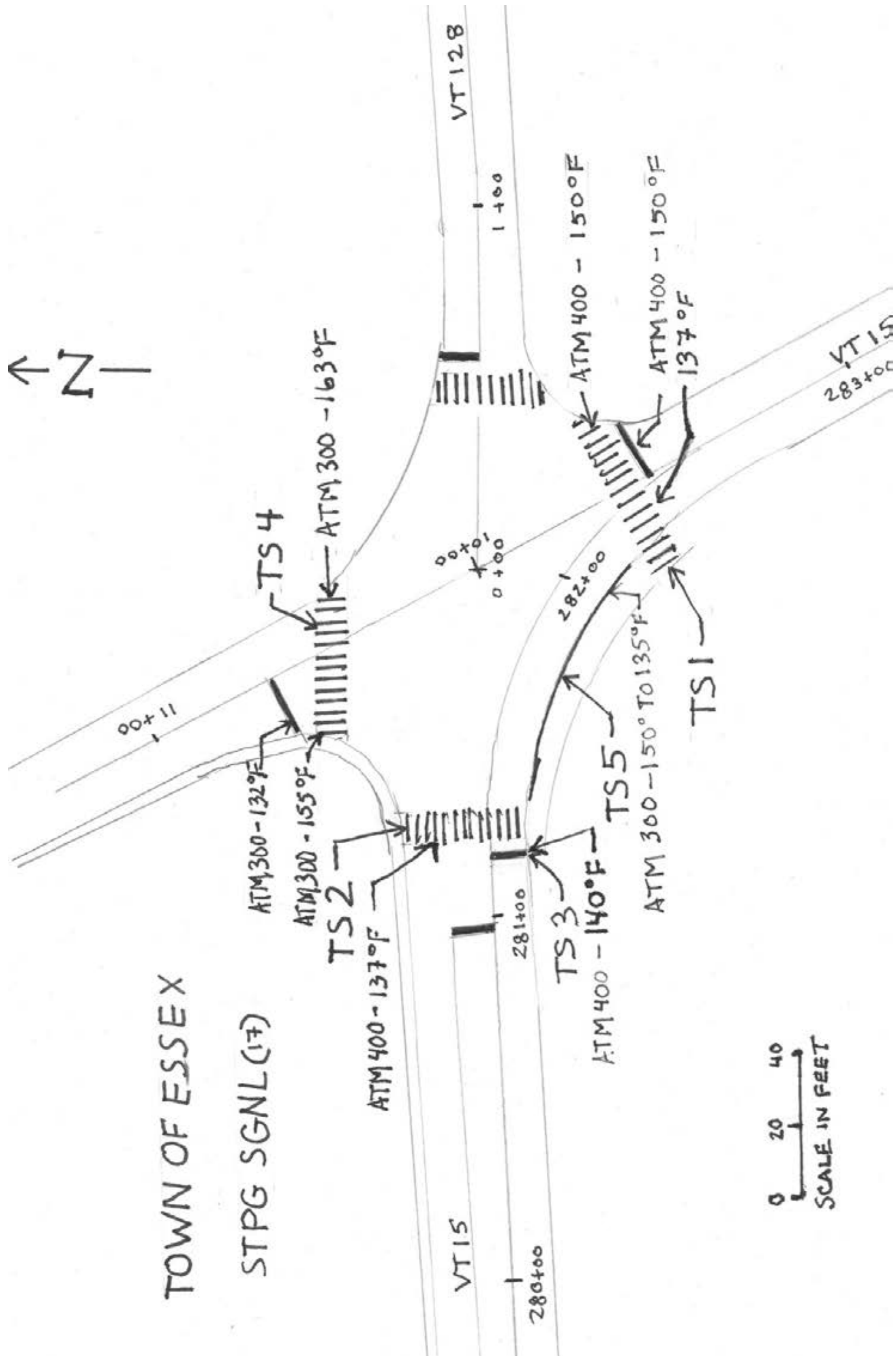

Figure B1 – Diagram of VT 15 and VT 128 intersection

A diagram of the entire project is provided in Figure B1. Included in the diagram are the locations of the five test sites selected for retroreflectivity measurement, along with the associated pavement temperatures at the time of ATM tape installation at each site.