Evaluation and Comparison of Snowplowable Raised Pavement Markings (SRPM) Waterbury/Bolton IM089-2(33) Final Report

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16. Abstract

In an effort to assess the overall performance and enhancement of lane delineation, the Vermont Agency of Transportation performed an investigation concerning 4 different compositions of snowplowable raised pavement markers installed in 2004.

Surveillance and testing measures included periodic site visits to examine any damage to the housing and lenses. This was accomplished by taking notes on each marker following a winter season to correlate cumulative damage to snow plow practices. In addition, the District was contacted to determine if any problems with regards to winter maintenance practices in relation to the snowplowable raised pavement markers were noted.

In general, the markers held up well in terms of durability throughout the 2.5 year monitoring period encompassing two winter seasons. A substantial increase in damage as well as missing lenses were noted between monitoring periods with 14% reported in 2005 and 43% observed in 2006 indicating a non-linear rate of deterioration. According to the data sets, the main failure criterion of the lenses appears to be damage rather than dislodging with 32% of damage reported in 2006 as compared to 11% missing. The Hallen and Avery-Dennison lenses were found to be more susceptible to dislodging from the housings while the Ray-O-Lite markers were found to be more vulnerable to damage.

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INTRODUCTION

Pavement markings provide an important means of communication for all roadway users and must be capable of conveying information during inclement weather and evening hours when there may be little to no contribution from overhead lighting. Standard markings, comprised of binder and reflective elements, are often obscured by rain or snow making lane delineation difficult. Raised pavement markers (RPMs), used to supplement conventional markings, have been widely implemented by state transportation departments for several years in order to provide enhanced delineation during inclement weather and evening hours. Comprised of plastic, ceramic, or occasionally metal, and manufactured in different shapes and sizes, these devices are designed to accommodate areas with little or no snowfall as well as those in the snow-belt region. However, studies have shown that these markers are susceptible to damage from winter maintenance practices due to profile and composition. Snowplowable raised pavement markers (SRPMs) differ in design from conventional RPMs by incorporating a lower ramp angle for improved plowability and a minimal exposure above the road surface. These cast iron markers are typically recessed into preexisting pavement and held into place with a two part epoxy.

In an effort to enhance visibility and delineation, the Vermont Agency of Transportation has examined snowplowable raised pavement markings numerous times over the past twenty years. Research completed in the 1980's concluded that the best use of SRPMS was in high accident areas. As stated in a report published in 1988, "due to the need to replace lenses annually in order to maintain a minimum of 50% efficiency, use of these markers can be recommended only in high accident locations or areas where geometric conditions require enhancement of standard traffic marking systems." A second evaluation was initiated in 2001 in order to furtherer Vermont's experience with these products and to test new types of markers.. As a result, 126 of Avery Dennison's model 101LPCR markers were installed in the southbound lane of Interstate 89 in the town of Waterbury between mile markers 67.55 and 64.75. The markers were applied into recessed grooves, at intervals of 80 feet, between the center skip lines on this section of highway. They were subsequently removed in September 2003 in anticipation of a 2004 resurfacing project. A third assessment commenced in 2004 in conjunction with a Category II research project, 2003-R-5, entitled, "Evaluation and Comparison of Snow Plowable Raised Pavement Markings" and the Waterbury/Bolton construction project IM089-2(33).

The following final report assesses the overall performance of the experimental pavement markings in terms of wear and durability. For comparative purposes, four different types of markers were used in conjunction with this research initiative. This report also contains information related to the experimental products and summarizes all surveillance and testing methods, data collection results and associated findings.

PROJECT DETAILS

The Waterbury/Bolton Project, IM089-2(33), constructed in 2004, included cold planing and resurfacing of the southbound lane and southbound interchange ramps with a leveling course and Type IV Superpave wearing course, pavement markings, Snowplowable Raised Pavement Markers, guardrails, signs and other incidental items. There were four types of SRPM were installed in association with the above referenced project from MM 68.70 to MM 64.23 for a total distance of 4.47 miles. The markers were placed in accordance with the standards in the Manual for Uniform Traffic Control Devices (MUTCD), Section 3B.13, "Raised Pavement Markers supplementing other Markers", which states that the markers should be placed at 80 feet intervals augmenting the skip lines. Markers incorporated into the study included the following: Dennison's Stimsonite LifeLite 101LPCR, Hallen H1010, Ray-O-Lite SnowLite CR150 and Ray-O-Lite SnowLite 200. The experimental markers were installed in the following sequence as shown in Table 1. Please note that all markers and lenses were supplied by the applicable manufacturer at no charge to the State.

Snowplowable Raised Pavement Markers, Waterbury-Bolton, IM089-2(33) Sequence of Installation				
Manufacturer	**Number of Markers**	**From (MM):**	**To (MM):**	**Total Length (miles):**
Avery Dennison 101 LPCR	96	68.70	67.25	1.45
Hallen H1010	100	67.25	65.73	1.52
Ray-O-Lite SnowLite 150	50	65.73	64.98	0.75
Ray-O-Lite SnowLite 200	50	64.98	64.23	0.75

Table 1 – Installation Sequence

Installation of the markers was completed in one day, Wednesday, June 23, 2004. The weather was clear and the temperature ranged from 65^{o}F to 72^{o}F throughout application. The installation process involved milling the pavement with specialized equipment to a depth of 1.71" +/- 0.06" in 80 foot intervals, as shown in Figure 1. Please note that recess depth is not as important as length due to the dimensions of the markers. Each marker has four "arms" located on the front and back of each marker. These arms extend from the body and lie flat on the surface of the pavement. All grooving operations were completed from roughly 9 AM to 12 PM. An air compressor was then used to remove remaining asphalt dust within the grooved areas. Once the recesses were adequately cleaned, an Epoplex MA50 two part epoxy manufactured by Epoplex was applied into the recessed areas. Any void space between the bottom of the marker and recess was filled completely with epoxy. Immediately, each marker was placed into the recess and firmly tamped into position, as shown in Figure 2. Placement of the markers began at approximately 9 AM and was completed by 4 PM. No problems were noted during installation. A detailed account of the installation is provided in an initial report, U2004-3, "Snow Plowable Raised Pavement Markers."

Figure 1 – Recess

Figure 2 – Hallen Marker with Epoxy

PRODUCT DETAILS

As stated previously, four different snowplowable raised pavement markers produced by three different manufacturers were incorporated into this assessment as follows: Avery Dennison from Niles IL, Hallen Incorporated from Gurnee, IL and Ray-O-Lite from Newark, OH. Please note that Avery Dennison was subsequently acquired by Ennis Paint Incorporated of Ennis, Texas, in May, 2006. Each marker consists of a housing and replaceable reflective insert. The following pertains to specific product information for each type of marker.

Avery Dennison - Stimsonite® brand LifeLite 101 LPCR Marker:

In accordance with the manufactures specification, the Avery Dennison-Stimsonite® brand LifeLite 101 LPCR raised snowplowable pavement markers are a narrow, "H-shaped" device designed with a low ramp angle to provide enhanced traffic marking delineation with better plowability than non-snowplowable markers. The two-component system consists of an uneven iron casting and reflector. The low-profile casting is constructed with two integral center rails that aid in providing protection to the reflector. The overall unit, shown in Figure 3, measures 10" long by 5.5" wide by 1.75" deep and weighs about 4.9 lbs. When properly installed, a total of 0.25" protrudes at a sloping angle above the road surface.

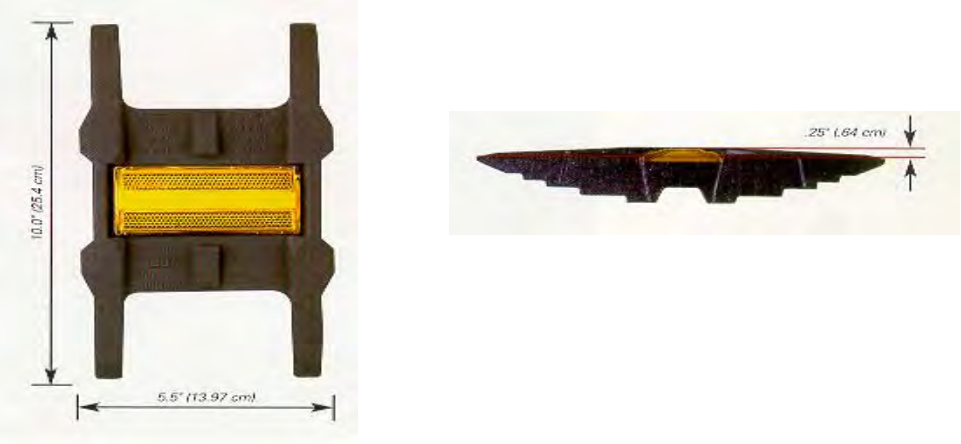

Figure 3 – Avery Dennison Stimsonite brand LifeLite 101 LPCR
(Photo supplied by Avery Dennison)

Hallen Products – Model H1010 Marker:

Hallen Products – Model H1010 raised pavement markers, displayed in Figure 4, are also a narrow, "H-shaped" device designed with a low ramp angle for better plowability. The reflector Series 190 is made by 3M . According to the manufacturer, the markers are abrasion and impact resistant. The overall unit, shown in Figure 4, measures 10" long by 4.875" wide by 1.75" deep and weighs about 5.8 lbs. When installed, a total of 0.25" protrudes above the road surface. The body is comprised of nodular iron that conforms to American Society for Testing and Materials (ASTM) A536, "Specification for Ductile Iron Castings."

Figure 4 – Hallen Products – Model H1010 Raised Pavement Marker
(Photo supplied by Hallen Products)

Ray-O-Lite Products – Snow-Lite Models CR150 and 200 Markers:

Ray-O-Lite Products – Snow-Lite Model CR150 features a medium profile design that increases the reflective area as compared to a low profile marker. The reflective insert has an abrasion resistant coating. Model CR150 comes with a center rail for additional protection of the reflective lens. The overall unit measures 9.25" long by 4.875" wide by 1.5" deep and weighs about 4.1 lbs. When installed properly a total of 0.25" protrudes above the surface of the pavement. Ray-O-Lite Products – Snow-Lite Model 200 is a low profile design for high speed plowing with minimal impact. When installed it protrudes ¼" above the roadway surface at the center and slopes down to zero at the ends.
The highly reflective insert also has an abrasion resistant coating. The overall unit measures 9.25" long by 5.875" wide by 1.5" deep and weighs 5.45 pounds. Both models are displayed in Figure 5.

Figure 5 – Ray-O-Lite Products – Snow-Lite 150 and 200
(Photo supplied by Ray-O-Lite)

Table 2 below contains a comparison between all of the markers that were assessed during this investigation:

Snowplowable Raised Pavement Markings, Waterbury-Bolton, IM089-2(33) Marker Detail Summary						
		Dimensions			Protrudes above Surface	Special Details
Manufacturer	Model	Length	Width	Height		
Avery Dennison	101 LPCR	10.000	5.500	1.750	1/4"	Center Rail
Hallen	H1010	10.000	4.875	1.750	1/4"	-----
Ray-O-Lite	CR 150	9.250	4.875	1.500	1/4"	Center Rail
Ray-O-Lite	200	9.250	5.875	1.500	1/4"	-----

Table 2 – Detail Summary

In closing this section on products details, one additional set of observations is warranted. The products that included a center bar also provided for a dual color presentation to the driver. The proper direction of approach was a traditional white dashed line. The reversed direction approach was a dashed red line. This feature was not assessed in this study. Further consideration of this feature, along with enhanced signage to prevent reversed direction travel is under consideration.

SURVEILLANCE AND TESTING:

All surveillance and testing was carried out in accordance with the workplan, WP 2003-R-5. In addition to monitoring the installation of the markers as discussed within the "Project Details" Section above, the markers were visually evaluated on a periodic basis to assess durability with consideration to winter maintenance activities and normal wear and tear produced by tire abrasion and ultraviolet radiation. In addition to conducting a visual assessment, photographs documenting current condition were also collected. This was accomplished by either setting up a sign package or driving along the shoulder. Any damage to the surrounding pavement was also recorded. Specifically, each lens was examined to determine if any were damaged or missing. In addition, the District was contacted to determine if the markers had any apparent effect on snow removal operations.

Unfortunately, there were some surveillance measures that could not be carried out as stated within the workplan. These included the collection of retroreflectivity, or luminance, measurements and the assessment of delineation performance under various light and weather conditions. While a retroreflectometer capable of gathering luminance data on standard markings was available throughout the investigation, it was not able to be modified for this specific investigation. Performance during various weather conditions was not recorded. However, personal experience supports their effectiveness during evening hours and inclement weather, as they were found to be extremely bright in comparison to the standard pavement markings by several Agency observers' reports to the author.

OBSERVATIONS:

Visual Assessments

As stated previously, the markers were visually assessed on Tuesday, November 29, 2005 and on Tuesday, December 5, 2006 seventeen and thirty months respectively, following application. The weather on November 29th as reported by WeatherUnderground.com was approximately 52^{o}F and overcast with light rain. The weather on December 5^{th} was approximately 18^{o}F and overcast. During the initial inspection on November 29^{th}, some of the lenses were found to be damaged or missing. All of the marking housings were found to be in good condition and intact. Failure modes for the markers during this time period is shown in Figures 6 through 9.

Figure 6 – Avery Dennison 101LPCR (2005)

Figure 7– Hallen H100 (2005)

Figure 8 - Ray-O-Lite SnowLite CR150 (2005)

Figure 9 - Ray-O-Lite SnowLite 200 (2005)

Significantly more damage was noted during the second inspection carried out on December 5th, 2006. It should be noted that a construction project, Waterbury-Bolton, ACIM089-2(30), was completed during the summer of 2006 prior to this inspection. According to the project plans, the project included the replacement of the concrete median barrier between the north and southbound lanes, landscaping between the northbound lane and US Route 2 and other incidental items including drainage improvements, pavement overlay along the shoulders directly adjacent to the barriers and line striping. During construction, traffic was reduced down to one lane and temporary barriers were placed along the center skip lines in both the north and southbound direction. These barriers were in close proximity or over many of the SRPMs in this study. In addition, while construction plans depicted milling only the shoulders, construction equipment marred the both passing lanes requiring the contractor to mill and fill both passing lanes. Consequently, some of the Avery Dennison snowplowable raised pavement markers were damaged and three were found to be completely missing all together. Therefore, it will be difficult to make any conclusive comparisons between the four types of markers. The failure mode for the markers on December 5th, 2006 is displayed in Figures 10 through 13.

Figure 10 – Avery Dennison 101LPCR (2006)

Figure 11– Hallen H100 (2006)

Figure 12 - Ray-O-Lite SnowLite CR150 (2006)

Figure 13 - Ray-O-Lite SnowLite 200 (2006)

The following tables provide an overall summary of results from visual assessments:

Damaged Snowplowable Raised Pavement Markers I-89							
Manufacturer	**Model #**	**Installed**	**Lens Damage (2005)**	**% Damage (2005)**	**Lens Damage (2006)**	**% Damage (2006)**	**% Increase**
Avery Dennison	101LPCR	95	2	2	24	25	23
Hallen	H100	97	6	6	20	21	14
Ray-O-Lite	SnowLite CR150	50	8	16	19	38	22
Ray-O-Lite	SnowLite 200	51	17	33	32	63	51
Total		**293**	**33**	**11**	**95**	**32**	**21**

Table 3 – Lens Damage

Missing Snowplowable Raised Pavement Markers I-89							
Manufacturer	**Model #**	**Installed**	**Lens Missing (2005)**	**% Missing (2005)**	**Lens Missing (2006)**	**% Missing (2006)**	**% Increase**
Avery Dennison	101LPCR	95	0	0	13	14	14
Hallen	H100	97	7	7	16	16	9
Ray-O-Lite	SnowLite CR150	50	0	0	2	4	4
Ray-O-Lite	SnowLite 200	51	1	2	1	2	0
Total		**293**	**8**	**3**	**32**	**11**	**8**

Table 4 – Missing Lenses

Overall, there was an increase in the rate of damaged or missing lenses in comparison to the previous inspection between 2005 and 2006. On average, roughly 14% of the lenses were damaged or missing in 2005 while 43% were found to be damaged or missing in 2006, an overall increase of 29% over the course of 13 months. It is important to note that damaged lenses continue to supply delineation of the traveled way, with varying intensity from the original lens configuration. From the information provided in Table 3, it would appear that the Ray-O-Lite lenses are more susceptible to damage.

However, when compared to Table 4, almost all of the Ray-O-Lite lenses were still present in 2006 as compared to 14 missing Avery Dennison lenses. It is noted above that some of the Avery Dennison markers were damaged during a subsequent construction project. When examining both the missing and damaged lenses, the Ray-O-Lite SnowLite 200 displayed the most damage at 67% while the Hallen H100 displayed the least damage at 38%, followed closely by the Avery Dennison 101LPCR markers at 40% and the Ray-O-Lite SnowLite CR150 at 46%. It is important to note that the Avery Dennison and Ray-O-Lite Snowlite CR150 markers contain the center rail. When comparing the overall performance of the two different Ray-O-Lite markers is does appear that the center rail protects the lenses from damage and stripping in addition to allowing the dual color lens.

Snow Plow Operations

District 6 personnel were contacted on Friday, June 15th, 2007 to discuss any potential snow plowing interferences in conjunction with the snowplowable markers. In 2003 during earlier evaluations, the Research and Development Unit had received complaints regarding the markers that were installed. Personnel explained that the blade of snowplow would bounce upon impact with the markers. However, Mike Wilder explained that there have been no reported problems with snow plow operations in this area since the application of the new SRPM in 2004. This may be due to the reduced height of the marker above the roadway surface. Previous markers may have protruded a greater amount above the roadway surface resulting in a greater impact to both the marker and the snow plow blade.

Crash Data

SRPM's were introduced to provide enhanced delineation during inclement weather and low light conditions. They are intended to improve driver preview distances. In a report published in 1988, the use of these markers was, "recommended only in high accident locations or areas where geometric conditions require enhancement of standard traffic marking systems." By providing increased preview distances and enhanced delineation of the driving lanes, one would hypothesize a reduction in vehicular accidents with the installation of SRPM's. In an effort to examine this principle, accident data was collected from the Traffic Research Section from 2001 through 2005 from MM 68.70 to MM 64.23. Crash data from both the north and southbound lanes were used to characterize the effect of the SRPM's. The northbound lane was considered the control for this analysis. In addition, ambient conditions were also noted to determine when the markers were most effective at reducing vehicular accidents. A summary of this analysis is provided in Table 5 below:

Number of Accidents from 2001 to 2005						
Year	Lane	Rain	Hail/Sleet/ Freezing Rain	Snow	No Precipitation	Total
2001	SB			1	2	**3**
	NB			2		**2**
2002	SB			2	5	**7**
	NB	1			1	**2**
2003	SB			3	3	**6**
	NB				2	**2**
2004	SB			2	2	**4**
	NB		1	3		**4**
2005	SB	2		3	5	**10**
	NB	1			2	**3**
Total	**SB**	**2**		**11**	**17**	**30**
	NB	**2**	**1**	**5**	**5**	**13**

Table 5 – Crash Data from MM 68.70 to MM 64.23

Given the information supplied in Table 5, there are no clear assertions regarding the effectiveness of the markers at reducing vehicular incidents. It is important to note that SRPM's have been present in the referenced location since 2001. More accidents were noted in the southbound lane during each year of the study with the exception of a tie in 2004. Additionally, there does not appear to be any correlations related to ambient conditions as a greater amount of crashes were reported in the southbound lane as compared to the northbound lane regardless of weather conditions. Overall, a greater number of crashes were noted within the southbound lane, more than twice that of the northbound lane. Therefore, the markers do not appear to be effective in reducing vehicular accidents.

ENVIRONMENTAL/MAINTENANCE FACTORS:

The test site area on I-89 south bound has one of the higher traffic volumes in the state with an AADT of 27200. This along with the total snowfall and the number of plow events (snow/ice control days) can affect the performance and durability of the markers. This information as well as other maintenance data for the test locations is provided in Table 6. It should be noted that while the total snowfall decreased from 2004-2005 to the 2005-2006 season the number of events (Snow Ice Control days) increased.

I-89 South Bound MM 64.23 to 68.00		
	2004-2005	2005-2006
Number Snow/Ice control Days	67	78
Inches of snow per year	89.7	44.8
AADT	27200	
Percent Truck Traffic	10.70%	
Type of De-Icing Chemicals	1 gal Calcium Chloride/ 1 ton Sodium Chloride	
Type of Grit	Salt/Sand	
Type of snow Blade	Carbide	
Angle of blade from Vertical	55-60 Degrees	
Average Yearly Air Temp. Range	7 to 85 degrees F	

Table 6 – Snow, Traffic and Maintenance Data

COST

The 2004 cost for installing the markers was bid at $60.00 each as part of the contract with the overall cost for installation of $17,760. This cost did not include the removal of the old markers or the cost of the new markers because they were supplied by the manufacturers. Current pricing for the markers and replacement lenses are reflected below in Table 7.

2007 Cost of Snowplowable Raised Pavement Markers						
Marker Brand	Model	Cost Ea.	Number Used	Total Material Cost	Installation Cost	Lens Replacement Cost
Avery Dennison (Ennis)	101 LPCR	$10.00	96	$960.00	$5,760	$3.75 ea.
Hallen Products	H1010	$7.50	100	$750.00	$6,000	$3.75 ea.
Ray-O-Lite	CR150	$7.10	50	$355.00	$3,000	$3.75 ea.
Ray-O-Lite	200	$7.10	51	$355.00	$3,060	$3.75 ea.
Total		**$31.70**	**297**	**$2,420**	**$17,820**	**$15.00**

Table 7 – Marker Cost

SERVICE LIFE

Service life estimates for each white line pavement marking were not determined from Table 3 and 4 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 all of the lenses were missing or damaged as shown in Figure 14. Please note that some of the Avery Dennison markers were damaged in association with a 2006 construction project.

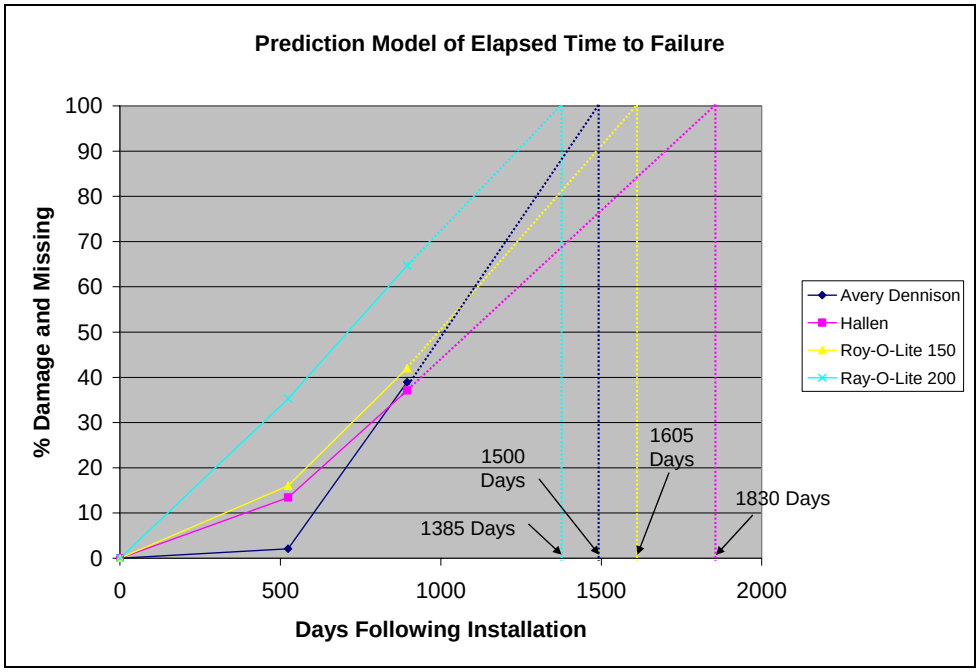

Figure 14 – Service Life Estimate

Estimated service lives for the white pavement markings are as follows in ascending order:

- Ray-O-Lite 200 – 1385 days
- Avery Dennison – 1500 days
- Ray-O-Lite 150 – 1605 days
- Hallen – 1830 days

Please note that a non-linear trend in the performance is shown within the graph above. By utilizing a linear performance model from 2005 to 2006, a highly liberal estimate of service life is shown within Figure 14. The actual life span will likely be shorter in duration. Also, given the additional damage of the Avery-Dennison markers due to construction practices, an increased slope between 2005 and 2006 has likely resulted in a more conservative life estimate as compared to the other markers.

COST BENEFIT:

All costs for the installation of the markers were paid as part of the Waterbury/Bolton Project, IM089-2(33). However, current pricing is provided in Table 7 above. Only the cost for each marking was assessed as the cost for installation and lens replacement would be a constant for all markers. The cost per month for each marking was calculated by dividing the total cost of each marker by the estimated service lives in months. The cost analysis is shown in Table 8.

SRPM Cost Analysis				
	Price per Marker	Elapsed Time		Cost Per Month
Marking Type:		Days	Months	
Ray-O-Lite 200	$10.00	1385	46	$0.22
Avery Dennison	$7.50	1500	49	$0.15
Ray-O-Lite 150	$7.10	1605	53	$0.13
Hallen	$7.10	1830	60	$0.12

Table 8 – Cost Estimate

As shown in the Table 8 above, it appears that the Hallen and Ray-O-Lite 150 markers are the most cost effective and provide the longest performance. It is interesting to note that the Ray-O-Lite 200 markers have the highest initial cost the shortest service life. In addition, while the Avery Dennison markers appear to be slightly more expensive than the Hallen and Ray-O-Lite 150 markers, this estimate may not accurately depict the actual cost per month as some markers were damaged from an adjacent project. Therefore, the installation of each marker is recommended with the exception of the Ray-O-Lite 200 markers.

SUMMARY:

Pavement markings provide an important means of communication for all roadway users and must be capable of conveying information during inclement weather and evening hours when there may be little to no contribution from overhead lighting. However, these markings decay overtime from environmental factors such as abrasion, fading pigments and ultraviolet radiation making lane delineation difficult. In accordance with the MUTCD, snowplowable raised pavement markers are intended to enhance delineation thereby reducing vehicular incidents. While recessed into the pavement, a portion of the marker protrudes above the pavement surface potentially resulting in damage from winter maintenance practices. On the other hand, these markers could also interfere with plow operations by causing the plow to bounce.

In an effort to assess the overall performance and enhancement of lane delineation, the Vermont Agency of Transportation has performed various investigations since the 1980's. In 2004, 4 different compositions of snowplowable raised pavement markers were installed in conjunction with a Waterbury/Bolton Project IM089-2(33) located in the southbound lane of Interstate 89 in the town of Waterbury between mile markers

67.55 and 64.75. Manufactured by three different companies, two of the markers contained a center rail for better plowability. Installation of the markers, spaced at 80' intervals in accordance with the MUTCD at a total length of 4.47 miles was completed in one day. This process included the grinding the pavement, removal of any grindings from the recessed area, followed by an injection of epoxy and subsequent placement of the markers. No problems were noted during installation.

Surveillance and testing measures included periodic site visits to examine any damage to the housing and lenses. This was accomplished by taking notes on each marker following a winter season to correlate cumulative damage to snow plow practices. In addition, the District was contacted to determine if any problems with regards to winter maintenance practices in relation to the snowplowable raised pavement markers were noted. Crash data collected from 2001 through 2005 by the Traffic Research Section was examined to determine if the markers were effective at reducing vehicle incidents. Both northbound and southbound crash was assessed to compare the number of reported incidents assuming that the northbound lanes were the control. Finally, a cost benefit analysis was performed on the markings based a projected rate of lens damage.

In general, the markers held up well in terms of durability throughout the 2.5 year monitoring period encompassing two winter seasons. A substantial increase in damage as well as missing lenses were noted between monitoring periods with 14% reported in 2005 and 43% observed in 2006 indicating a non-linear rate of deterioration. According to the data sets, the main failure criterion of the lenses appears to be damage rather than dislodging with 32% of damage reported in 2006 as compared to 11% missing. The Hallen and Avery-Dennison lenses were found to be more susceptible to dislodging from the housings while the Ray-O-Lite markers were found to be more vulnerable to damage. According to District 6, there were no reported problems with snow plow operations in relation to the markers. Crash data does not necessary indicate that the markers were effective in reducing vehicular accidents. However, it is important to note that there is a severe curved roadway alignment through most of this roadway segment. Personal experience during evening hours and inclement weather proved that the markers do increase delineation of the driving and passing lane. Finally, the Ray-O-Lite 150 and Hallen markers were found to be the most cost effective marking closely followed by the Avery Dennison markers. However, once again it should be noted that the Avery Dennison markers were damaged during an adjacent construction project during the summer of 2006. Therefore, it is difficult to make any conclusive comparisons between the four types of markers.

As concluded in 1988, installation of the snowplowable raised pavement markers are recommended only in high accident locations or areas where geometric conditions require enhancement of standard traffic marking systems. However, future installations of the Ray-O-Lite 200 markers are not recommended at this time.

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