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EVALUATING PAVEMENT MARKINGS ON PORTLAND CEMENT CONCRETE (PCC) AND VARIOUS ASPHALT SURFACES

Results of Year 1, 2, 3, and 4 Data Collection

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A report of the findings of
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Evaluating Pavement Markings on Portland Cement Concrete (PCC)
and Various Asphalt Surfaces

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16. Abstract

The Illinois Department of Transportation (IDOT) uses a variety of different pavement marking systems and has experienced a wide range of pavement marking performance. In an effort to maximize marking performance and to optimize marking selection, IDOT initiated a research project to evaluate the performance of all currently approved marking types to develop a pavement marking selection guide based on performance results.

The purpose of this project is to evaluate the performance of pavement markings on both portland cement concrete (PCC) and hot-mix asphalt (HMA) pavements over a period of four years. Field investigations were conducted to gather data on the durability and visibility of markings and the compatibility between markings and pavement materials. From the results of the study and a life-cycle cost analysis, Applied Research Associates (ARA) developed a pavement marking selection guide. Because the successful performance of a marking depends largely on controlling many variables during the installation of the marking, this guide includes pavement marking installation inspection methods for use by IDOT inspectors.

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- **Illinois DOT:** Funding, identification of test sites, data collection, and lane closures during data collection.
- **Illinois Tollway:** Results of on-going pavement marking research, test sites, and lane closures during data collection.
- **Applied Research Associates:** Project management, literature review, survey of industry and agency representatives, test site selection, data collection, data processing and analysis, and development of pavement marking selection guide and pavement marking installation inspection procedures.
- **Omar Smadi and Neal Hawkins (Center for Transportation Research and Education at Iowa State University):** Assistance with development of survey questionnaire.

DISCLAIMER

EXECUTIVE SUMMARY

The Illinois Department of Transportation (IDOT) uses a variety of different pavement marking systems and has experienced a wide range of pavement marking performance. In an effort to maximize marking performance and to optimize marking selection, IDOT initiated a research project to evaluate the performance of all currently approved marking types and develop a pavement marking selection guide based on performance results.

The purpose of this project is to evaluate the performance of pavement markings on both portland cement concrete (PCC) and asphalt pavements over a period of four years. Field investigations were conducted to collect data on the durability and visibility of markings and the compatibility between markings and pavement materials. The two metrics employed for evaluating the performance of the markings were presence and retroreflectivity. A Pavement Marking Index (PMI), a standardized process for combining both metrics to present one performance value, was used to represent the overall condition of the markings; a minimum PMI represented the markings' end of service life (ESL).

Test sections were evaluated for four testing cycles: after placement, after first winter, after second winter, and after third winter. The original study period was supposed to end after the second winter; however, the weather was exceptionally mild during the second winter. While many of the markings were expected to have service lives longer than two years, most markings were still far from the end of their service lives. Therefore, an extension was approved to evaluate the test sites for one additional cycle.

A PMI of 60 represents a marking's failure limit or ESL. After the second winter, only 16%of the test sites had a PMI below 90. After the final data collection, 35% of the test sites had a PMI below 90, and three test sites reached the end of their service lives. Twenty three test sites were restriped before failure was concluded by data. The end of service life for all sites that did not reach the failure limit was determined by projecting retroreflectivity and presence performance curves until the calculated PMI fell below 60. As expected, recessed markings performed better than surface-applied markings, and southern area markings, having less abrasion from snow removal, performed better than northern area markings.

Applied Research Associates, Inc. (ARA) produced a pavement marking selection guide based on the results of the study and a life-cycle cost analysis. Because the successful performance of a marking depends largely on controlling many variables during the installation of the marking, this guide includes pavement marking installation inspection methods for use by IDOT inspectors.

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CHAPTER 1 OVERVIEW

1.1. BACKGROUND

The Illinois Department of Transportation (IDOT) uses a variety of different pavement marking systems and has experienced a wide range of pavement marking performance. In an effort to maximize marking performance and to optimize marking selection, IDOT initiated a research project to evaluate the performance of all currently approved marking types and develop a pavement marking selection guide based on performance results. IDOT solicited research proposals through the Illinois Center for Transportation (ICT). In December 2009, ICT awarded project R27-77, “Evaluating the Compatibility, Durability, and Visibility of Pavement Markings on Portland Cement Concrete and Various Asphalt Surfaces,” to Applied Research Associates, Inc. (ARA).

The purpose of this project is to evaluate the performance of pavement markings on both portland cement concrete (PCC) and hot-mix asphalt (HMA) pavements over a period of four years. Field investigations were conducted to collect data on the durability and visibility of markings and the compatibility between markings and pavement materials. ARA will produce a pavement marking selection guide based on the results of the study and the life-cycle cost analysis. Because the successful performance of a marking depends largely on controlling many variables during the installation of the marking, this guide will include pavement marking installation inspection methods for use by IDOT inspectors.

The Illinois Tollway contributed the results of their on-going pavement marking research to the ICT project. Data from the Illinois Tollway research effort is presented throughout Section 2 and in Appendix B.

1.2. TEST METHODS

The two metrics selected for evaluating the performance of pavement markings were retroreflectivity and presence.

1.2.1. RETROREFLECTIVITY

Retroreflectivity indicates how visible markings are to drivers at night. Retroreflectivity is reported as the coefficient of retroreflected luminance, R_L, which is defined by the American Society for Testing and Materials (ASTM) as the ratio of the luminance of a surface to the normal illuminance on the surface. Retroreflectivity of pavement markings is the reflected light from the pavement marking (seen by the driver) versus the source light (from the vehicle headlamps) directed at the pavement marking. Figure 1 depicts the components of R_L.

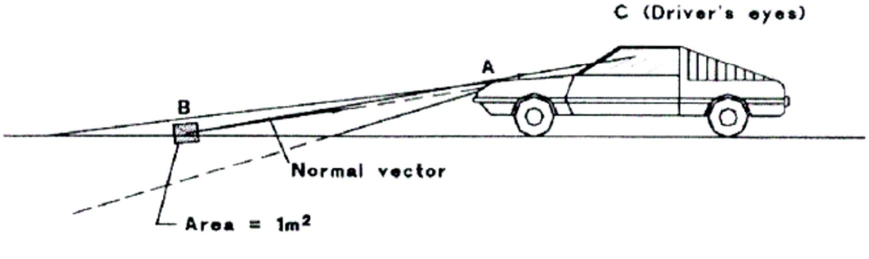


Figure 1. Depiction of roadway retroreflection (from Publication No. FHWA-SA-93-001).

During field investigations, retroreflectivity measurements were collected with a hand-held 30-meter geometry retroreflectometer, a Delta LTL-X, shown in Figure 2.

Figure 2. Delta LTL-X Retroreflectometer.

Retroreflectivity testing was performed in accordance with ASTM E 1710-05, "Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer."

1.2.2. PRESENCE

Presence, the second metric for evaluating pavement marking performance, is an indication of a marking's durability, which represents a marking's ability to remain bonded to the pavement and in place. ARA developed a binary image analysis program specifically for measuring a marking's presence. Photos of the markings are taken under standardized lighting conditions and are then processed with the image analysis software. Results from the software report presence as the percentage of material missing from the pavement marking. Figure 3 is an example of a pavement marking photo viewed in the analysis program.

Figure 3. Image analysis program.

To standardize the lighting for each pavement marking photo, ARA devised a simple box that blocks all outside light and illuminates markings with lights mounted inside the box. The camera mounts on top of the box. Figure 4 shows a camera box placed over a pavement marking and Figure 5 shows the interior of the box.

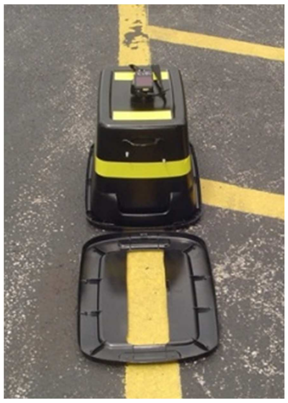


Figure 4. Camera box.

Figure 5. Camera box interior.

The images of markings with anomalies, such as latency on top of the marking or pavement cracks through the marking, are either edited or removed prior to processing through the image analysis program. Therefore, reported presence values (percentage missing) are not affected by anomalies that are not related to the marking's durability performance.

The number of retroreflectivity test points and photos was adapted from sampling guidelines detailed in ASTM D 6359-99, "Standard Specification for Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments." Skip line testing puts researchers close to live traffic because traffic control procedures close one lane of traffic only . Therefore, when possible, testing was conducted on edge lines only to keep researchers a full lane away from traffic.

Pavement conditions were monitored near the markings for associated distresses during field investigations. Observed distresses were recorded and then summarized in this report.

1.3. PAVEMENT MARKING INDEX

Developing IDOT's pavement marking selection guide requires setting a minimum performance standard that represents a marking's end of service life. A method was needed for using both metrics, retroreflectivity and presence, to understand marking performance over time and set a minimum performance limit. The ICT Technical Review Panel (TRP) approved using the Pavement Marking Index (PMI), developed by ARA, to accomplish this objective. The PMI is a standardized process for combining both performance measures to generate one value that represents the overall condition of a pavement marking; the minimum PMI represents the end of service life. PMI calculation is similar to the calculation for a Pavement Condition Index (PCI) (Shahin 1994). The index has a maximum value of 100. The deduct values for each performance measure are obtained from graphs based on the measured performance. The deduct values are then totaled and a corrected total is read from another graph. Finally, the corrected total is subtracted from 100 to give the final index value. The following sections describe (1) the retroreflectivity deduct curve, (2) the presence (or percentage missing) deduct curve, and (3) PMI calculation.

1.3.1. RETROREFLECTIVITY DEDUCT CURVE

The deduct curve for retroreflectivity sets the maximum deduct value to correspond with a minimum required retroreflectivity value. The deduct curve is established with current performance standards and can be modified to correspond to a future federal standard. Table 1 lists the current proposed minimum maintained retroreflectivity levels for longitudinal pavement markings (Federal Register 2010).

Table 1. Proposed "Table 3A-1" for the MUTCD
(Minimum Maintained Retroreflectivity Levels[1] for Longitudinal Pavement Markings)

	Posted Speed (mph)		
	≤ 30	35 - 55	≥ 55
Two-lane roads with center-line markings only. [2]	n/a	100	250
All other roads. [2]	n/a	50	100

1. Measured at 30-m geometry in units of mcd/m^2/lux
2. Exceptions:
   A. When RRPMs supplement or substitute for a longitudinal line (See Section 3B.13 and 3B.14), minimum pavement marking retroreflectivity levels are not applicable as long as the RRPMs are maintained so that at least 3 are visible from any position along that line during nighttime conditions.
   B. When continuous roadway lighting assures that the markings are visible, minimum pavement marking retroreflectivity levels are not applicable.

A great number of the markings evaluated by ARA fall into the category of "All other roads" and "Speed limit ≥ 55 mph"; therefore, the maximum deduct value was set to correspond with a retroreflectivity of 100 mcd/m^2/lux, as shown in Figure 6. Additional deduct curves could be created for other combinations of road types and speed limits.

An exponential formula was selected so that the curve becomes asymptotic as retroreflectivity approaches infinity. Retroreflectivity values of 300 or higher correspond to a deduct value of approximately zero. The shape of the curve was created so that the largest deducts occur after retroreflectivity drops below 140 mcd/m^2/lux. Although the wide variety of available marking types can produce a large range of retroreflectivity values, having one deduct curve allows for comparisons among various marking types.

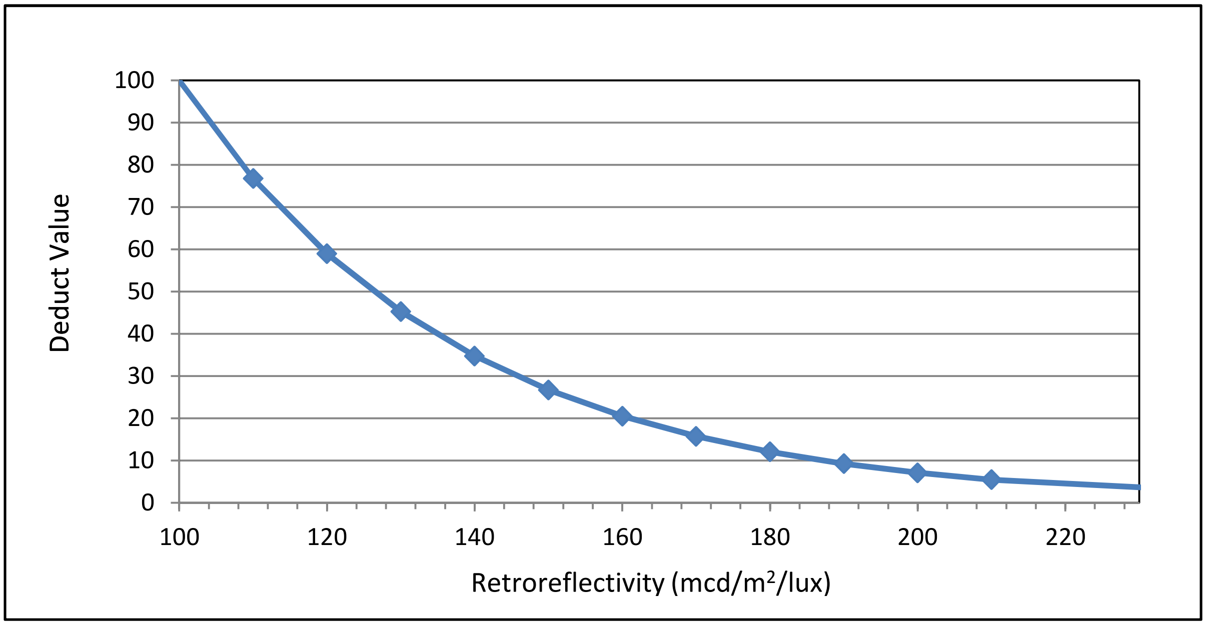


Figure 6. Deduct curve for retroreflectivity.

1.3.2. PRESENCE DEDUCT CURVE

The deduct curve for presence was developed based on experienced analysis of presence data and observed increases in the rate of bond deterioration. The presence deduct curve is shown in Figure 7.

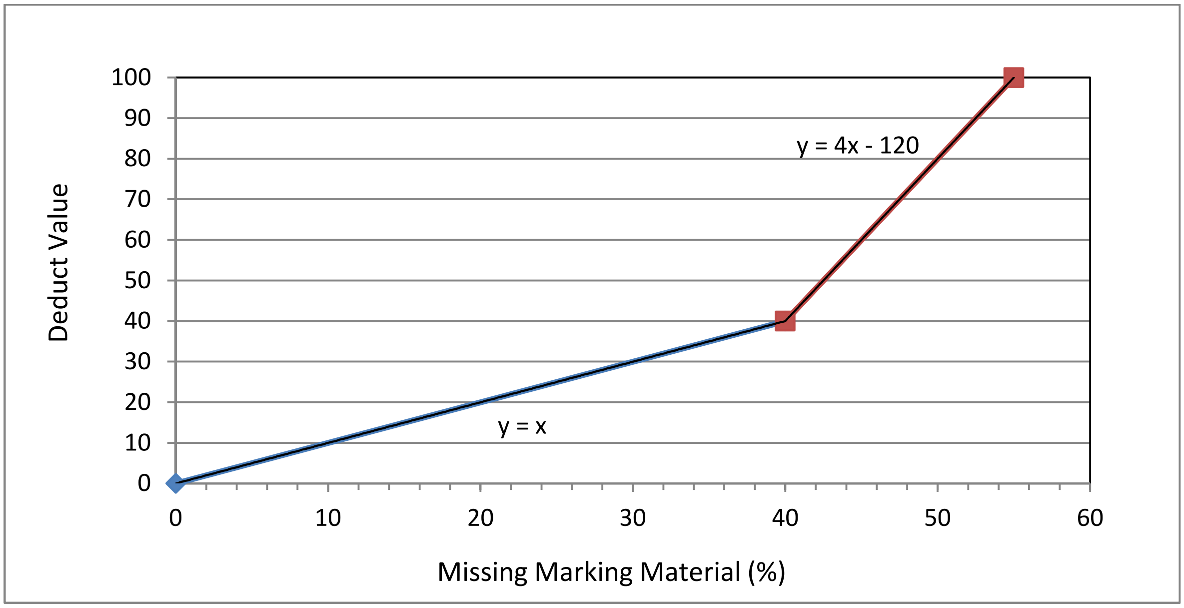


Figure 7. Deduct curve for presence (percentage missing).

The shape of the presence deduct curve is opposite to the shape of the retroreflectivity deduct curve because as the percentage missing increases, the deduct values for the condition index should increase. When a marking is 100% present, the deduct value should be zero, so the y-intercept was set to zero. Based on expert opinion of presence data analyzed to-date and on observation of presence deterioration, the curve's initial slope is gradual up to 40% missing. However, the slope increases beyond 40% missing because deterioration is more rapid past this point. All presence values at or above 55% missing will have a deduct value of 100. Markings with 55% or more missing material were considered to provide minimal value to the traveling public.

Presence deducts, as presented here, are only applicable to solid line markings. Structured markings, which begin with coverage values close to 55% missing, would obviously fail quickly. If the PMI were to be standardized for all markings, including structured markings, then a standard method for taking photos from an angle representing a driver's perspective should be developed.

Although a marking's presence is not dependent on retroreflectivity, retroreflectivity is partially dependent on a marking's ability to remain bonded to a pavement surface. A marking can be 100% present and have little or no retroreflectivity if there is no reflective media on it. However, if a marking material becomes de-bonded, then there is less surface area returning light back to the driver's eyes. Retroreflectivity also depends on other variables such as bead embedment, bead condition and retention, and type of reflective media. Figure 8 clearly shows the relationship between retroreflectivity and presence and represents most of the retroreflectivity and presence data that ARA has collected to-date. The data is collected from a variety of marking types and ages, and each point typically represents an average of 20 readings; the graph supports the points selected in the presence deduct curve.

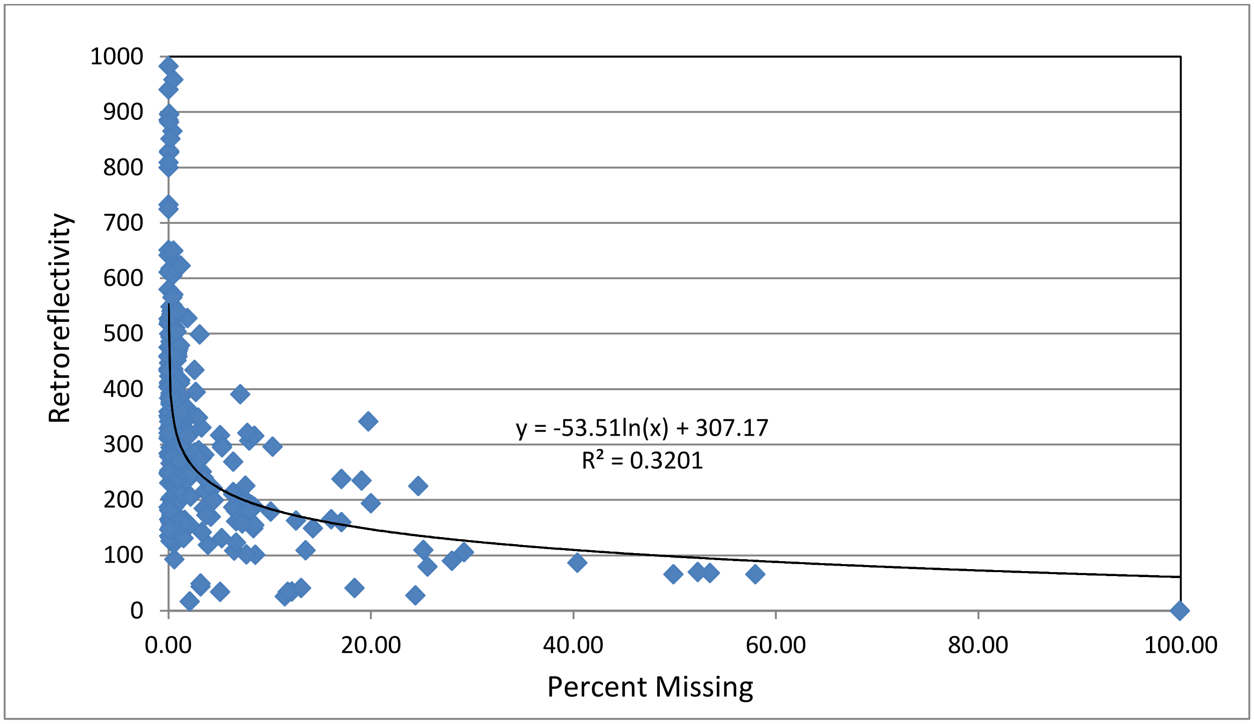


Figure 8. Relationship between retroreflectivity and presence.

1.3.3. PMI CALCULATION

After the retroreflectivity and presence deduct values are determined from their respective curves, the two values are added and then a Corrected Deduct Value (CDV) is determined from the graph in Figure 9. The function of the CDV is to adjust the total deduct to a 100-point scale.

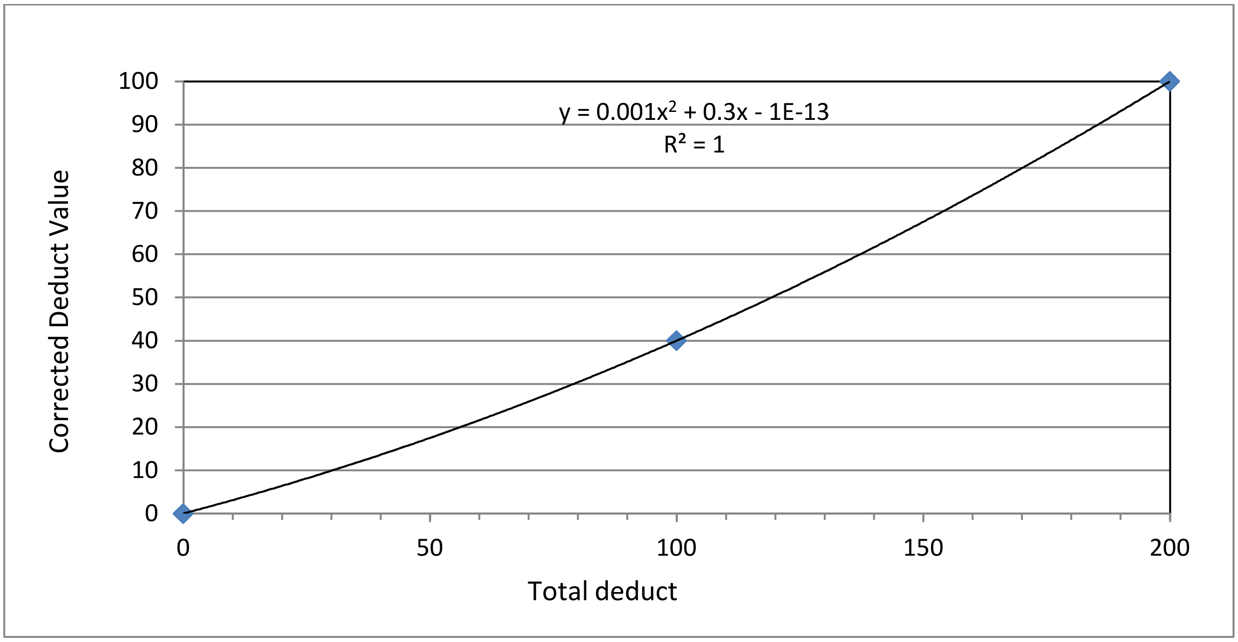


Figure 9. CDV curve for calculation of PMI.

The PMI is then calculated as follows:

$$PMI = 100 - CDV$$

A condition index typically has a threshold for pass/fail, and the pass/fail threshold for PMI was set at 60. Therefore, a CDV of 40 would produce a failure rating for a marking. Because it is possible to have a marking that is 100% present (presence deduct = 0) and has a retroreflectivity value less than 100 mcd/m^2/lux (retroreflectivity deduct = 100), the total deduct value of 100 must correspond with a CDV of 40 in order to fail a marking that does not meet the minimum retroreflectivity standard.

1.4. TEST SITE CRITERIA

In May 2010, ARA met with the ICT TRP to identify criteria for selecting pavement marking test sections. At the beginning of this process, ARA recommended dividing the state into three zones corresponding to snowfall regions because of the significant deterioration of markings caused by snow removal. The Midwest Regional Climatology Center records the number of snowfall occurrences at or above 1 in. of snow and plots this data on maps in the form of snowfall curves. Figure 10 is an Illinois contour map of the number of snowfall days with over 1 inch of snow.

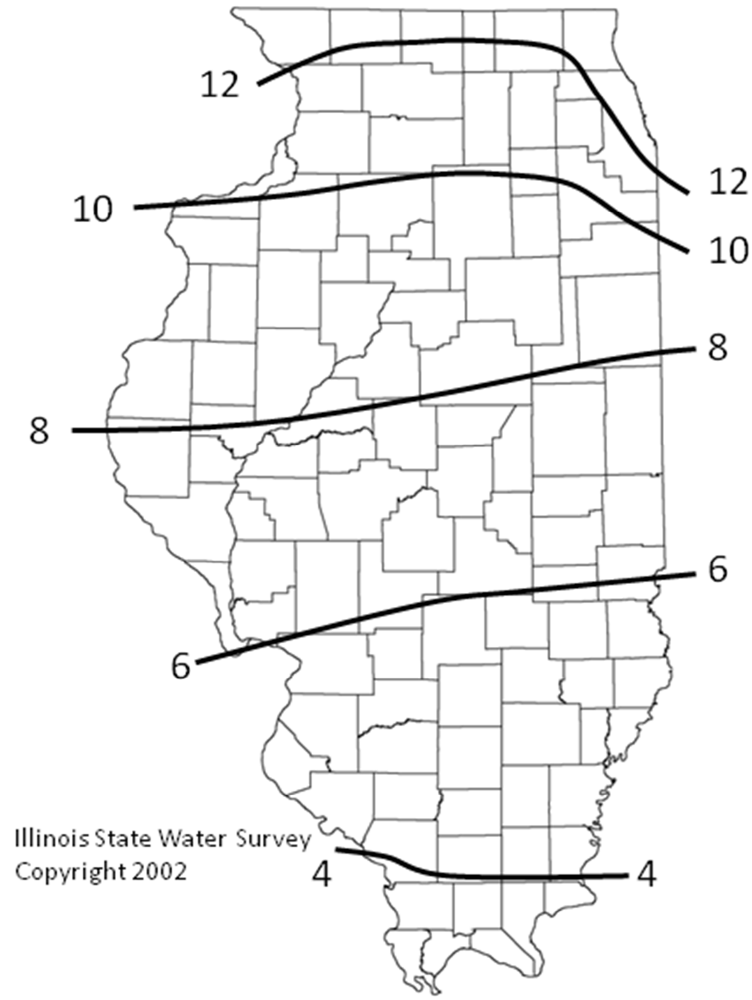


Figure 10. Average number of days with snowfall at or above 1 in.

The snowfall contour map is superimposed over the IDOT District map in Figure 11. The 10-in snowfall contour line is approximately at the same location as Interstate 80, and the 6-in snowfall contour line is approximately at the same location as Interstate 70. Therefore, I-80 was selected as the boundary between the northern and central snowfall zones, and I-70 was selected as the boundary between the central and southern snowfall zones.

Because there are many variables to consider when selecting a pavement marking system, the TRP had in-depth discussions about the criteria for selecting test sites. The TRP agreed on a list of variables to evaluate for each IDOT pavement marking system. The list of variables provided guidance for identifying test sites and will contribute to the comparisons needed to develop the pavement marking selection guide. The list of selected variables for each marking product is presented in Table 2; cells highlighted in grey indicate selected variables.

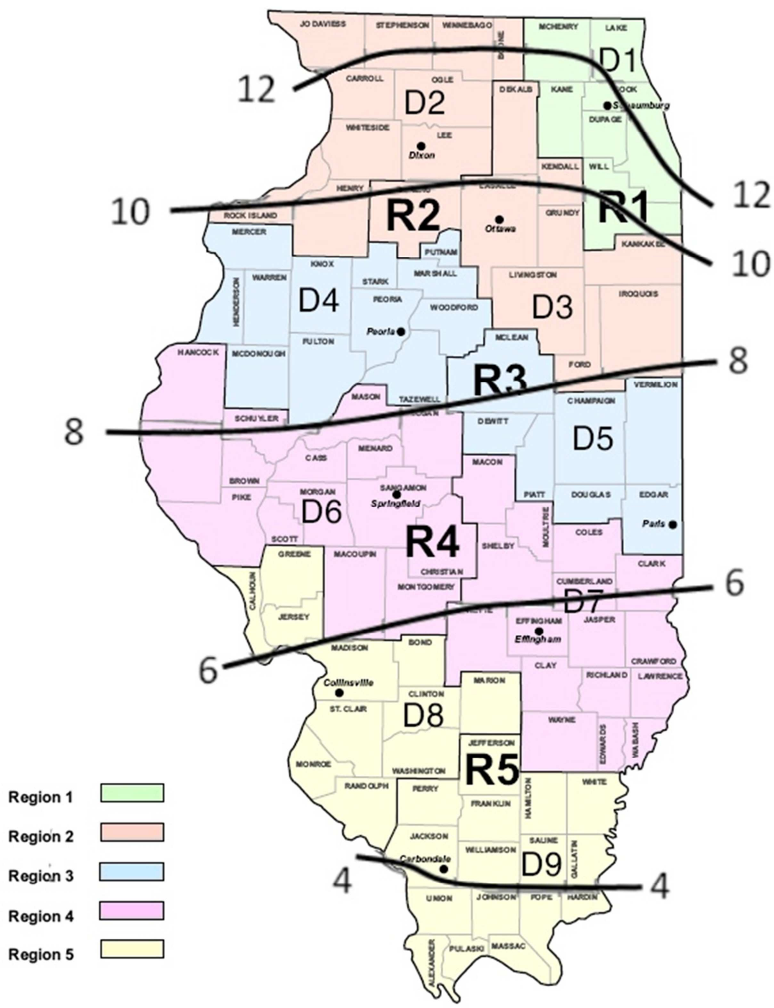


Figure 11. Illinois snowfall contours over IDOT District map.

Table 2. Variables Selected for Evaluating Marking Performance

Variables to Evaluate			Marking Types					
			Paint	Thermoplastic	Tape	Epoxy	Polyurea	Urethane
ADT	Low	(≤ 10,000)						
	High	(> 10,000)						
Climate	Zone 1	(Northern IL)						
	Zone 2	(Central IL)						
	Zone 3	(Southern IL)						
Striping Contract	New							
	Maintenance							
Pavement Type	HMA							
	PCC							
	Chip Seal							
	Micro-Surface							
Resin Type	Hydrocarbon	(Petroleum)						
	Alkyd	(Wood)						
Surface Application	Surface							
	Recessed	Inlay						
		Groove						
Wet R_l	Wet Reflective (WR)							
	Non-Wet Reflective							
Application Technique	Truck	(Long Lines)						
	Hand Cart	(Arrows & Legends)	Include when present					

Based on the variables selected for evaluation, a table was generated for each marking type to display all desired test sites for that marking. Table 3 shows 24 desired test sites for polyurea markings; cells highlighted in grey indicate selected variables.

Table 3. Desired Test Sites for Polyurea

Variables to Evaluate			Polyurea Test Sites																							
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
ADT	Low	(≤ 10,000)																								
	High	(> 10,000)																								
Climate	Zone 1	(Northern IL)																								
	Zone 2	(Central IL)																								
	Zone 3	(Southern IL)																								
Striping Contract	New																									
	Maintenance																									
Pavement Type	HMA																									
	PCC																									
	Chip Seal																									
	Micro-Surface																									
Resin Type	Hydrocarbon	(Petroleum)																								
	Alkyd	(Wood)																								
Surface Application	Surface																									
	Recessed	Inlay																								
		Groove																								
Wet R_l	Wet Reflective (WR)																									
	Non-Wet Reflective																									
Application Technique	Truck	(Long Lines)																								
	Hand Cart	(Arrows & Legends)																								

1.5. SELECTED TEST SITES

Test sites were identified from existing pavement construction contracts and maintenance striping contracts. After searching and coordinating between ARA, members of the TRP, and IDOT District representatives, a list of potential test sites was created. All of these sites were plotted on a map as shown in Figure 12. The name of the site corresponds to the pavement marking material and test site number as listed on the tables of desired test sites. Redundant sites are labeled with letters following the name.

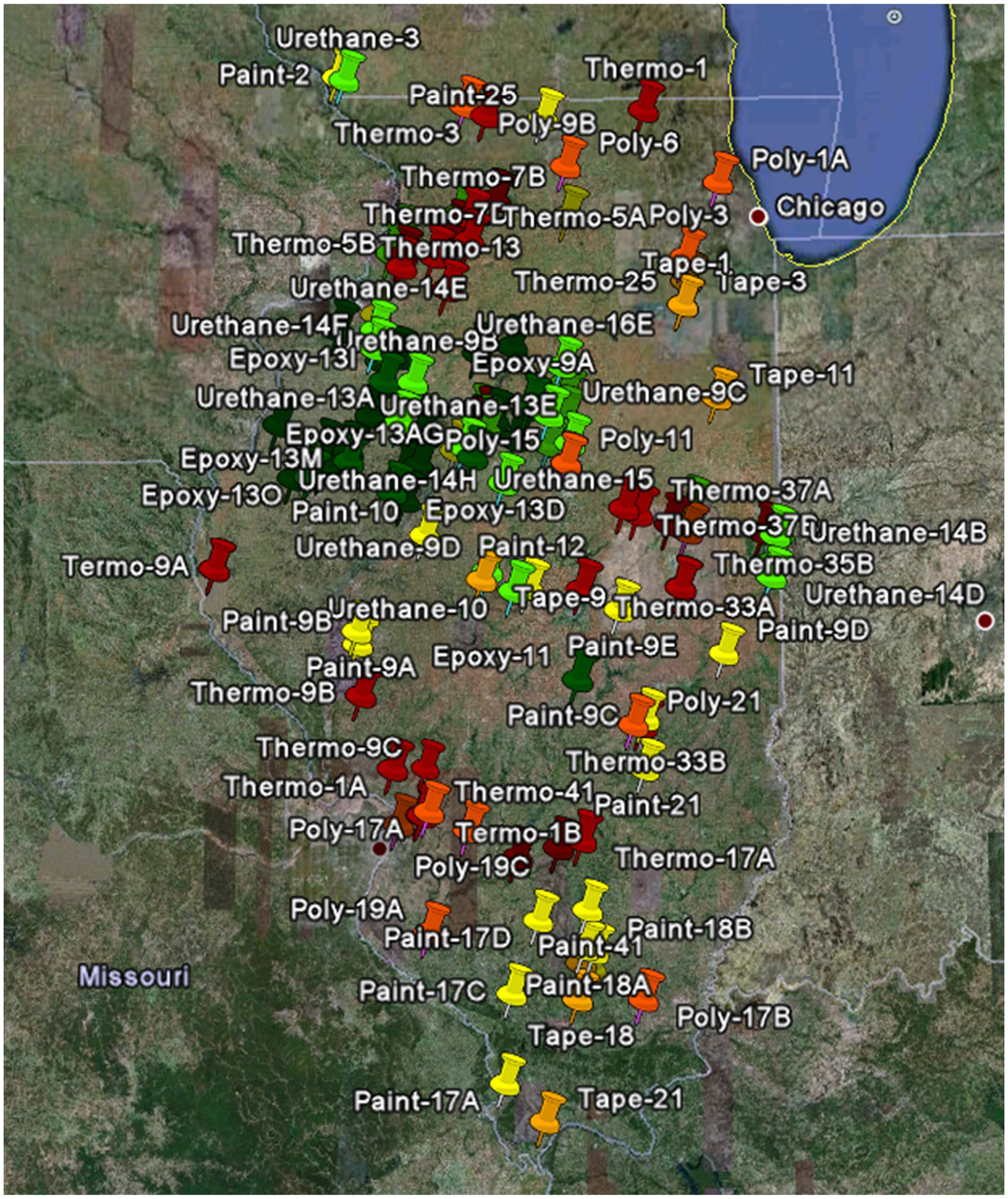


Figure 12. Original map of potential test sites.

Reducing the list of test sites to a manageable number for data collection required identification of the proximity of sites to IDOT maintenance facilities because IDOT crews were providing traffic control for data collection. All single sites that were too distant from groupings of other sites and a great number of redundant sites were eliminated. Figure 13 shows a map displaying the original list of sites selected for testing. Although the final list is considerably shorter than the sites identified on the lists of desired sites, it reflects a good distribution of variables being evaluated across the state. For the development of the pavement marking selection guide, the TRP agreed that some assumptions could be made to fill in a few data gaps.

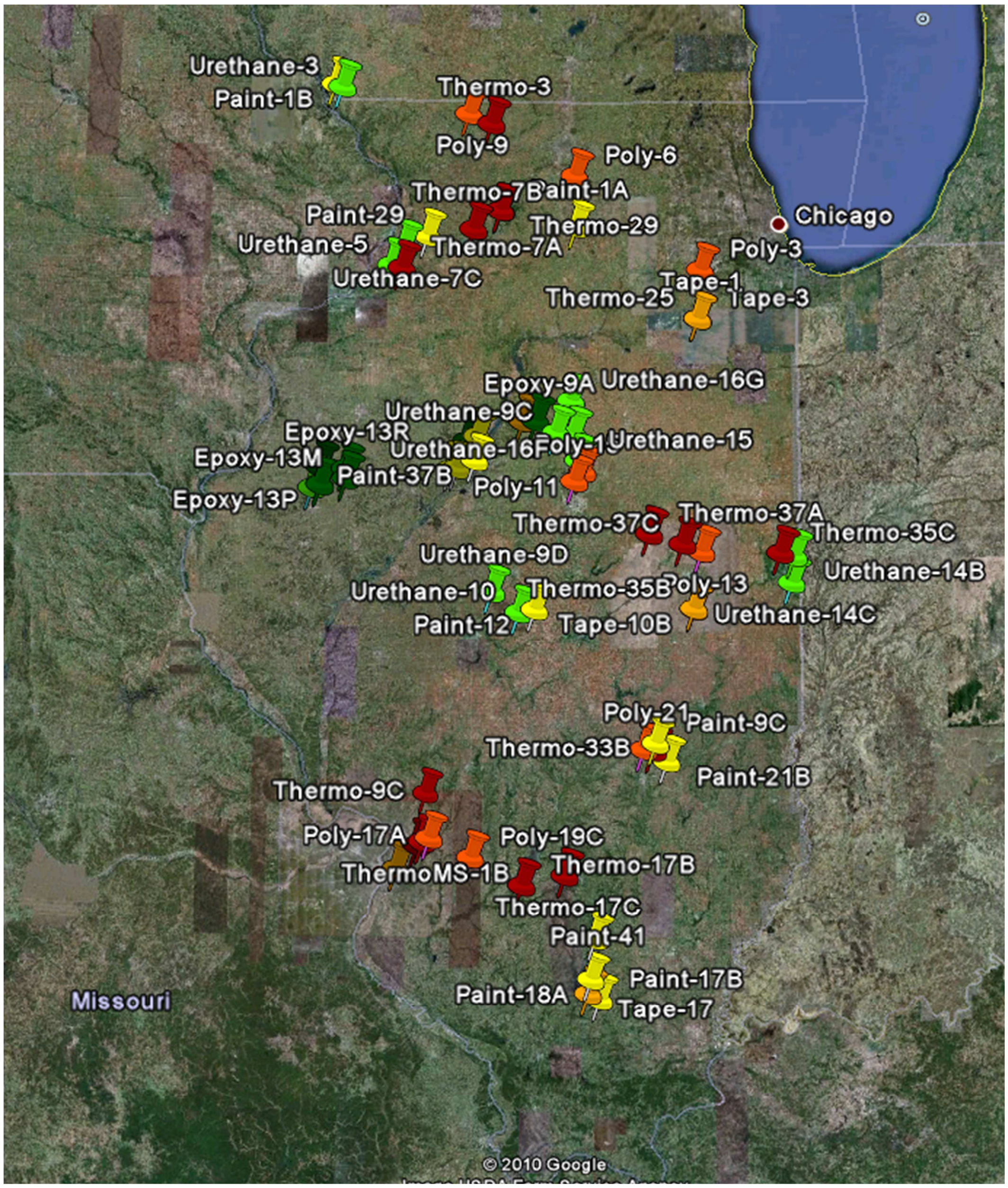


Figure 13. Map of selected test sites.

Although not all sites had been placed, data collection began in October 2010. A few sites were never installed because of a shortage in national supply of pavement marking materials and other contract-related issues. A final list and maps of tested sites is provided in Appendix A.

CHAPTER 2 DATA ANALYSIS

As discussed in the Test Site Criteria Section, snow removal plays a large part in the deterioration of pavement markings. The amount of snowfall differs from year to year in each zone, so the Midwest Regional Climatology Center provided contour maps of accumulated snowfall for each winter of this study. The contour maps are shown in

Figure 14. During the first winter (2010-2011), snowfall amounts were average for Illinois. However, during the second winter (2011-2012), snowfall amounts were considerably less than the amounts typical for Illinois, and many markings exhibited little or no deterioration in performance during the second year. The third winter (2012-2013) had slightly lower accumulated snowfall levels than the first winter.

Differences in yearly snowplow events affect the rate of bead loss and marking material loss. The data collected in this study shows that some markings deteriorated very little over the 2011-2012 winter.

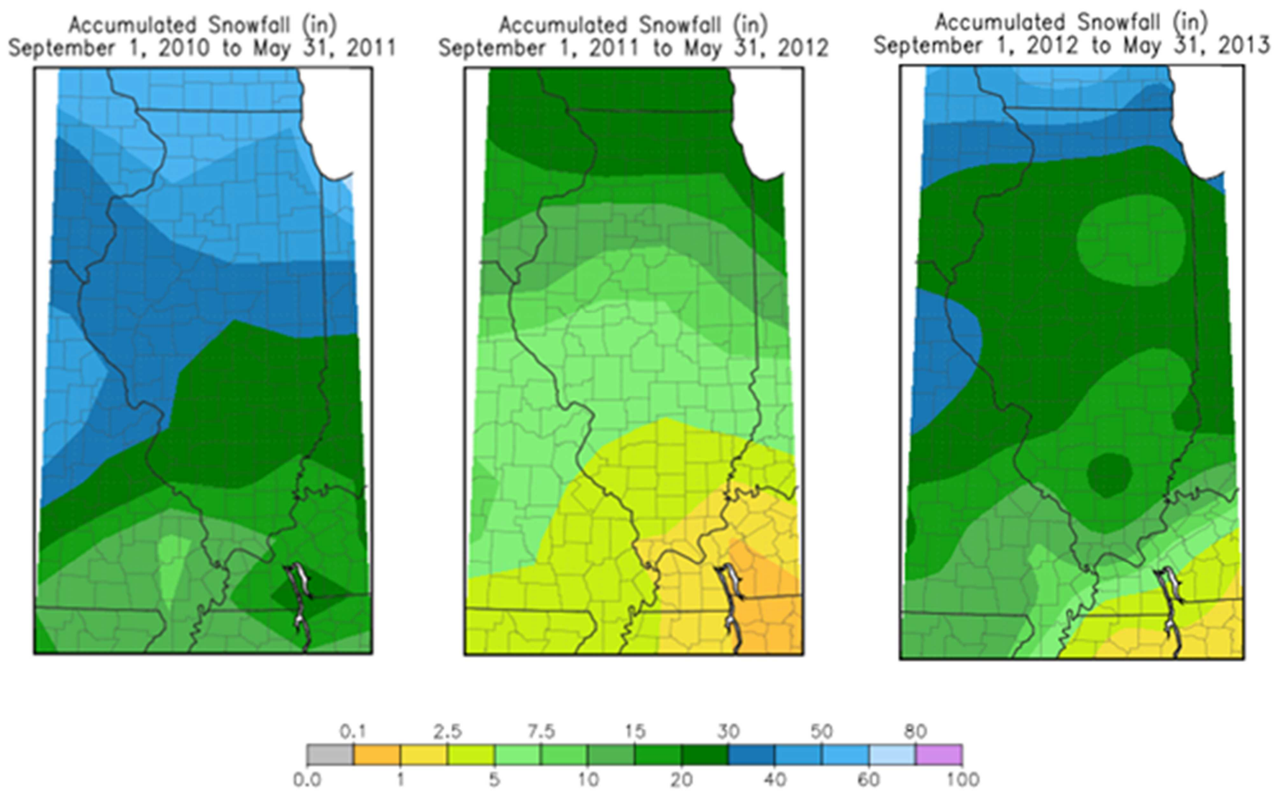


Figure 14. Accumulated snowfall contour maps provided by the Midwest Regional Climatology Center.

2.1. PAINT

The average retroreflectivity, presence, and PMI data for each maintenance paint site and new construction paint site are listed in Table 4 and Table 5, respectively. Most paint sites are restriped annually per current practices and therefore the material experiences one winter only. Paint-41, a new construction paint site, which had the highest retroreflectivity after one winter, was not restriped in order to be tested again in 2012.

Paint maintenance striping has been generally observed to last longer than single-application paints. However, the lack of records specifying the number of paint applications limits all attempts to conduct comparisons. Therefore, it was decided to test the new construction sites, with the exception of Paint-18A and Paint-41, a second time in 2011 after each site received a new layer of material in order to observe improved performance and acquire comparable data. Table 6 shows data of double-layered markings on new pavement.

Figure 15, Figure 16, and Figure 17 show the retroreflectivity values versus the marking's age at the time of testing, displaying the marking's retroreflectivity performance over time. Each figure contains two graphs. The first graph uses a retroreflectivity scale of zero to 1000 mcd/m^2/lux to show the full range of possible retroreflectivity values and allow easier comparison with graphs of other marking material types. The second "zoomed" graph uses a narrower scale to show a more detailed view of each site's performance.

Paint-18A, the only paint on concrete, was the only site that was completely destroyed. Poor adhesion and plowing caused a loss of almost 100% of the markings during one winter and therefore retroreflectivity data could not be collected. The site with the lowest retroreflectivity, Paint-37B, was a maintenance paint site. Paint-37A and 37B had very similar retroreflectivity in both 2010 and 2011. However, the presence (percentage missing) of Paint-37A was almost 10 % higher in 2011. Paint-37A had significantly more pavement distresses, such as cracking, near the edge line than any other paint sites. Cracks propagate chipping of the marking material, and cracks generate voids where dirt can collect. Many cracks in the Paint-37A site collected enough soil to sustain the growth of vegetation.

After the 2010-2011 winter, Paint-41 had the highest average retroreflectivity at 245 mcd/m^2/lux. It was the only paint site that was not restriped in 2011. The site's retroreflectivity remained relatively high in 2012 at 229 mcd/m^2/lux.

Paint-9F was the only paint site tested in 2013 because it was the only one that was not restriped in the summer of 2012.

Table 4. Maintenance Paint Data

Site #	ADT	Zone #	Pavement Type	Application	2010			2011		
					R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI
13	2200-3650	2	HMA	Surface	285	0.3	100	182	6.8	94
21B	4650-5600	3	HMA	Surface	307	0.7	100	152	1.7	91
37A	8,300	2	HMA	Surface	197	0.5	97	128	15.9	76
37B	16,200	2	HMA	Surface	206	0.6	98	122	6.2	76

Table 5. New Construction Paint Data

Site #	ADT	Zone #	Pavement Type	Application	2010			2011			2012		
					R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI
1A	2,700	1	HMA	Surface	266	0.2	100	231	5.2	97	-	-	-
9C	4,200	2	HMA	Surface	225	0.8	99	167	7.0	92	-	-	-
9F	25	2	HMA	Surface	266	1.6	99	175	7.2	93	-	-	-
12	1,100	2	Micro-Surface	Surface	225	1.1	98	196	16.2	92	-	-	-
17B	4,200	3	HMA	Surface	232	0.9	99	199	17.8	92	-	-	-
18A	1,060	3	PCC	Surface	218	0.2	98	-	99.5	0	-	-	-
41	8,600	3	HMA	Surface	271	0.6	99	245	5.1	98	229	7.9	96

Table 6. Double-Layer Paint Data

Site #	ADT	Zone #	Pavement Type	Application	2011			2012			2013		
					R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI
1A	2,700	1	HMA	Surface	345	0.4	100	300	2.0	99	-	-	-
9C	4,200	2	HMA	Surface	355	0.4	100	272	1.1	99	-	-	-
9F	25	2	HMA	Surface	284	1.2	99	278	2.3	99	162	2.5	92
12	1,100	2	Micro-Surface	Surface	255	0.6	99	254	1.1	99	-	-	-
17B	4,200	3	HMA	Surface	243	4.6	98	249	4.6	98	-	-	-

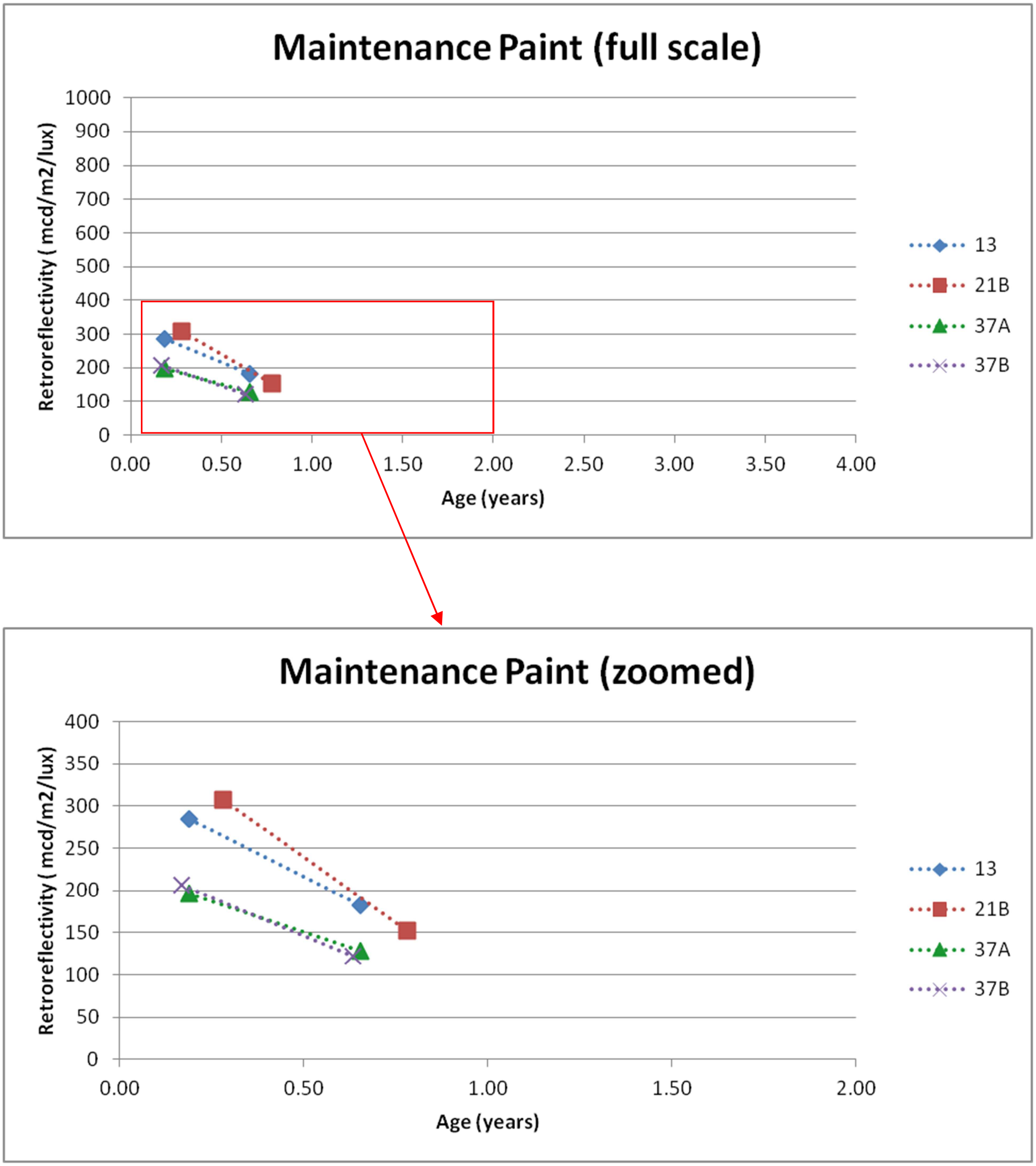


Figure 15. Maintenance paint retroreflectivity.

Figure 15 shows the 2010 and 2011 data for maintenance paint sites. The sites were restriped following the 2011 data collection, so data was not collected in 2012 and 2013.

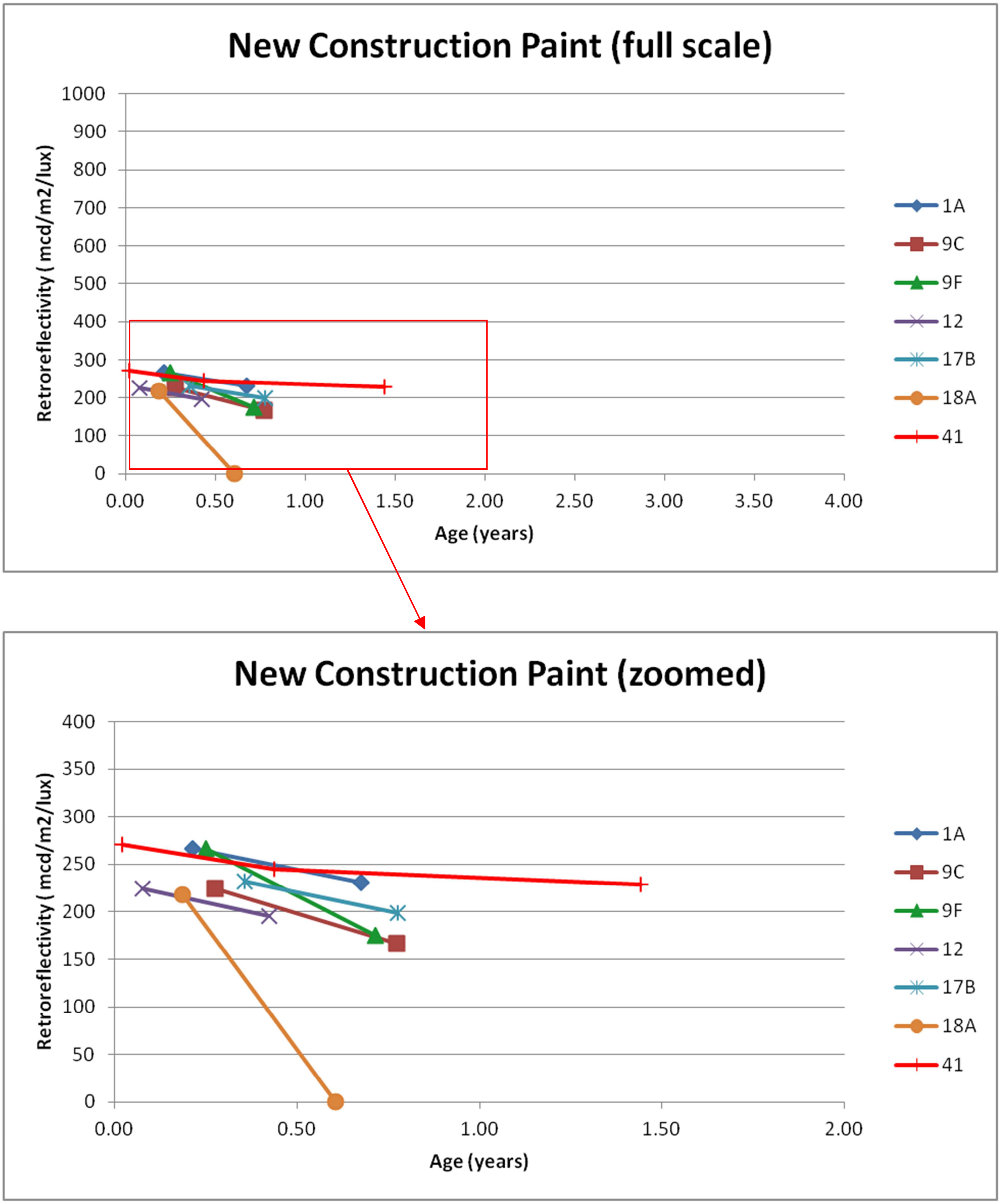


Figure 16. New construction paint retroreflectivity.

Figure 16 shows the data for maintenance paint sites. The sites were restriped following the 2011 data collection except for Paint-41, which was restriped following the 2012 data collection.

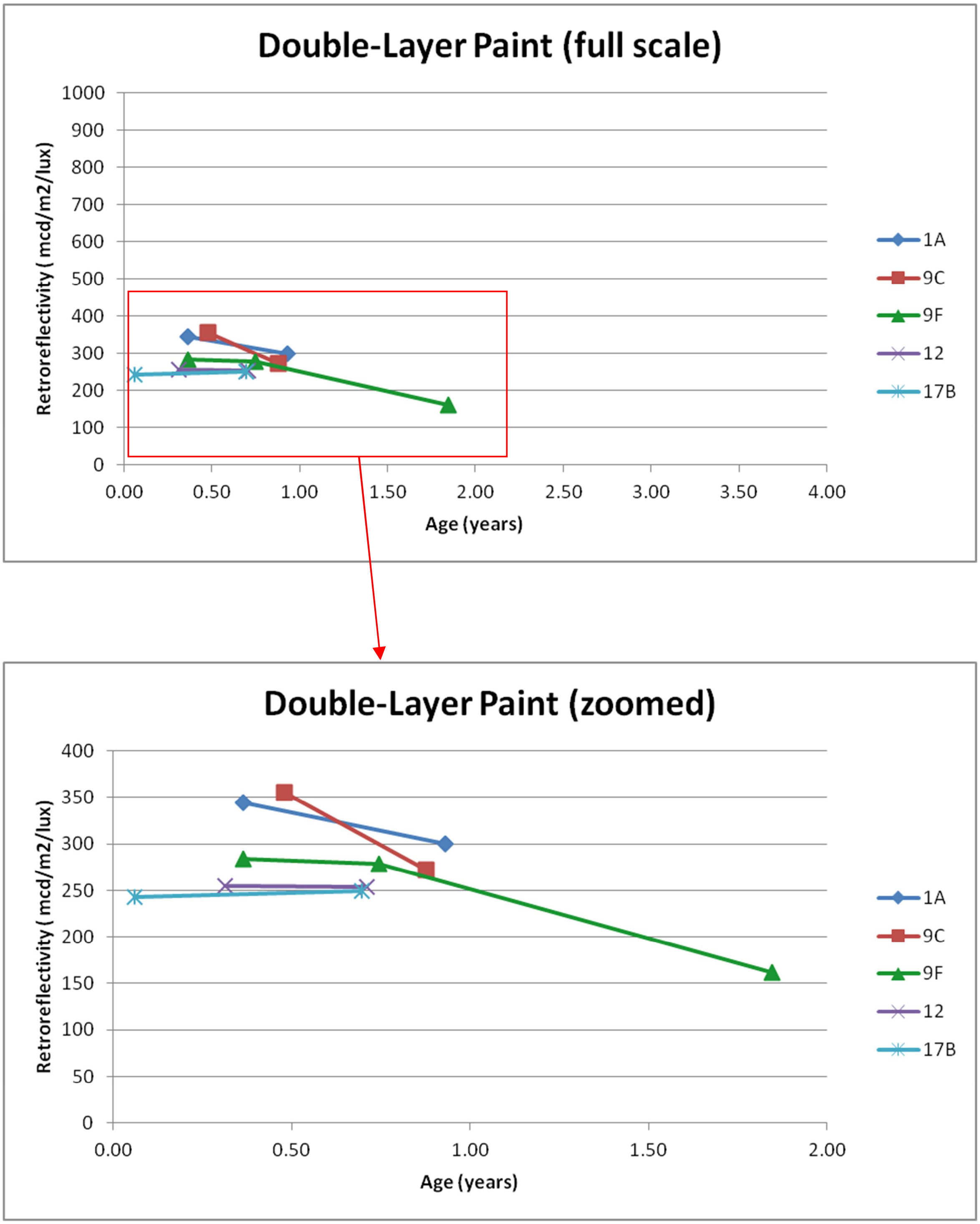


Figure 17. Double-layer paint retroreflectivity.

Figure 17 shows the data for new construction paint sites with a second layer of material. The first data set was collected after the sites were restriped in 2011. Despite high retroreflectivity averages, all sites were restriped following the 2012 data collection except for Paint-9F.

Figure 18 displays the initial retroreflectivity with one layer to the initial retroreflectivity after application of the second layer. The initial retroreflectivity with a double coat of material is higher than the initial retroreflectivity with a single coat for all five restriped paint sites. Figure 19 shows the difference in retroreflectivity after one winter. Again, the double-layer paint has higher values at every site. However, this difference may be exaggerated because of the mild winters of 2011 and 2012.

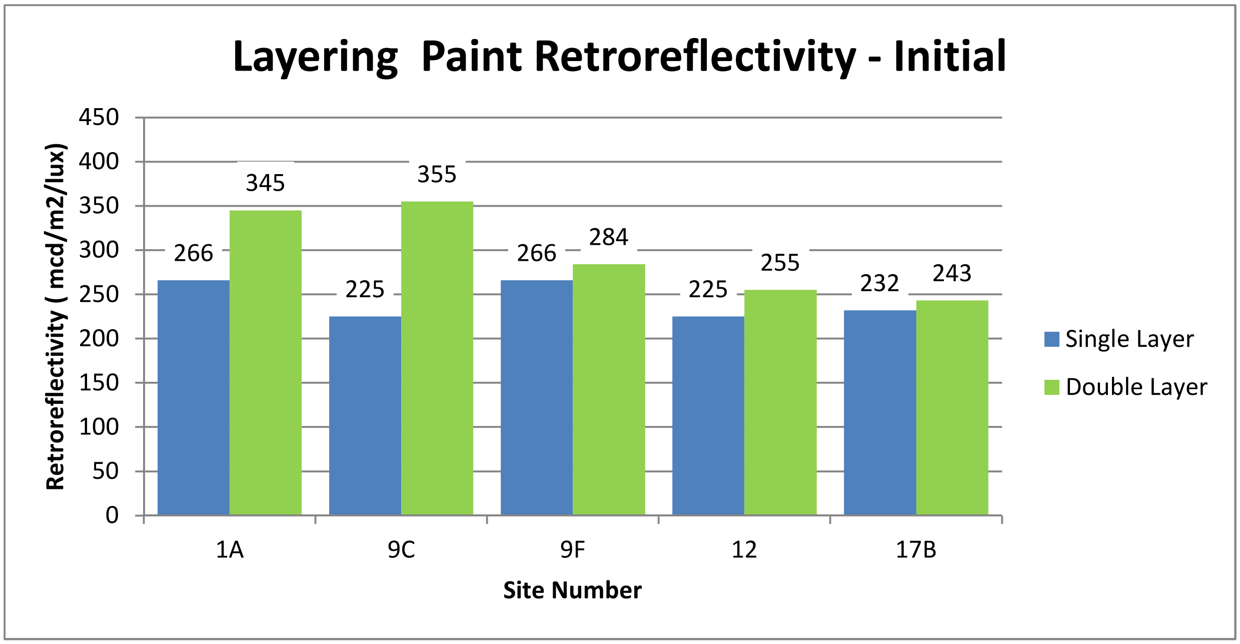


Figure 18. Initial paint retroreflectivity for single and double layers.

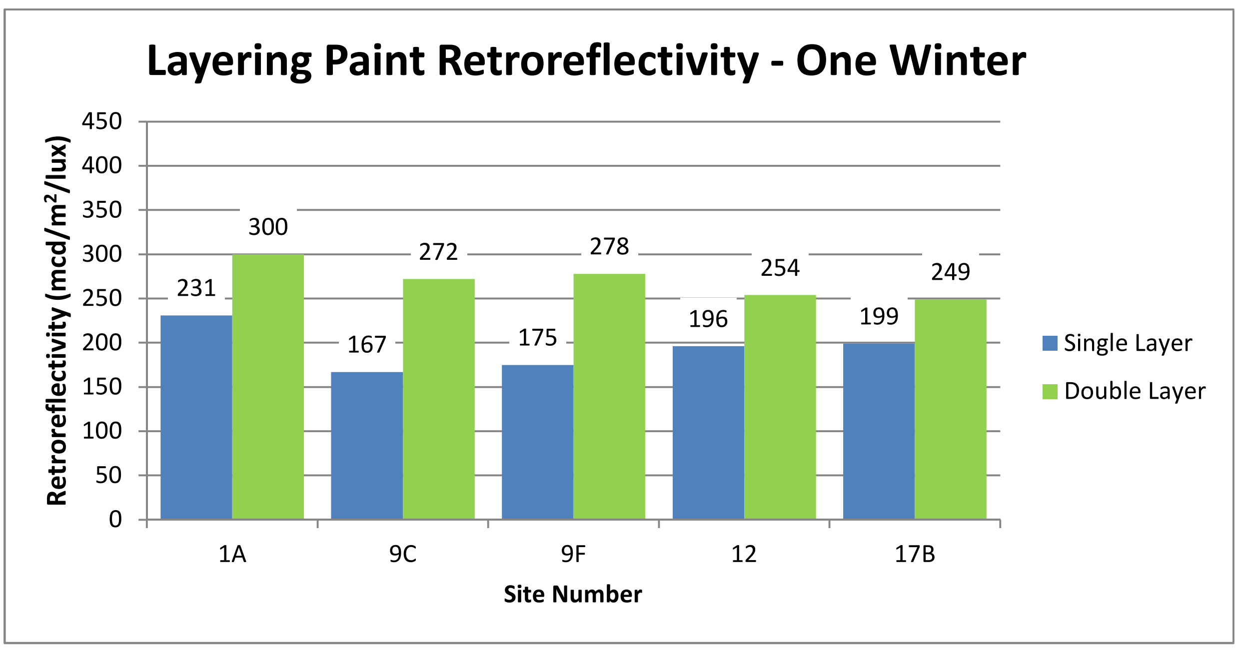


Figure 19. Paint retroreflectivity for single and double layers after one winter.

The presence data for all paint sites is shown in Figure 20, Figure 21, and Figure 22. The values of most maintenance sites are similar to the values of new construction sites. The performance of Paint-21B, however, was similar to double-layer paint. All double-layer sites lost less than 5% material over their first winter.

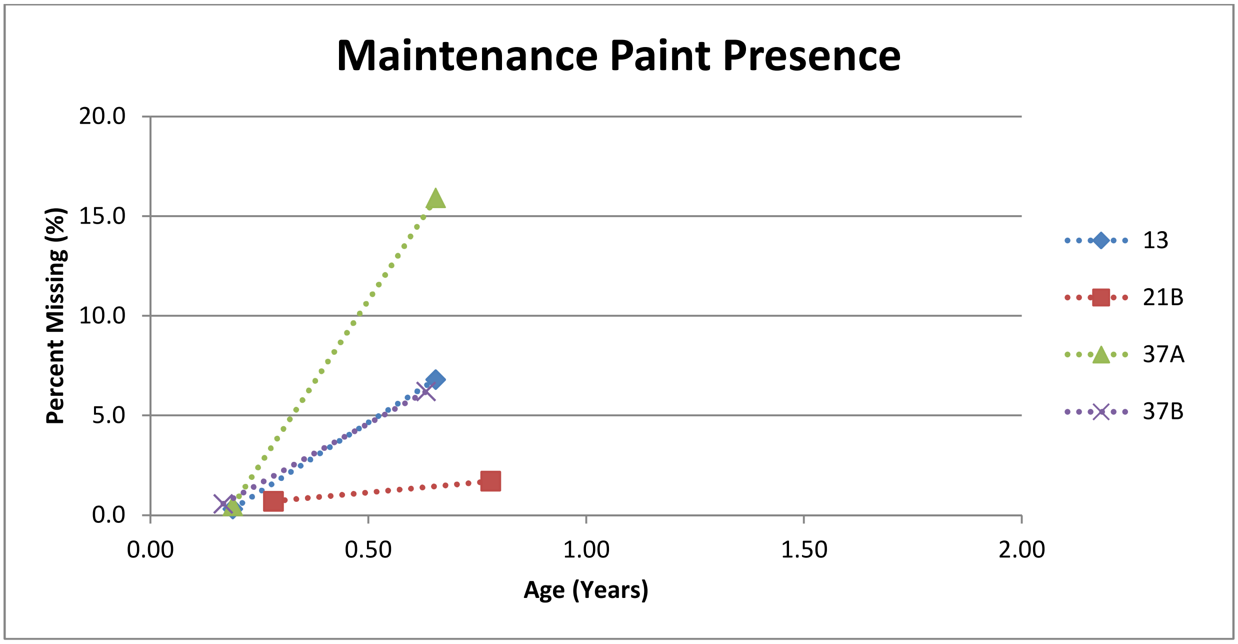


Figure 20. Maintenance paint presence (2010 and 2011 data).

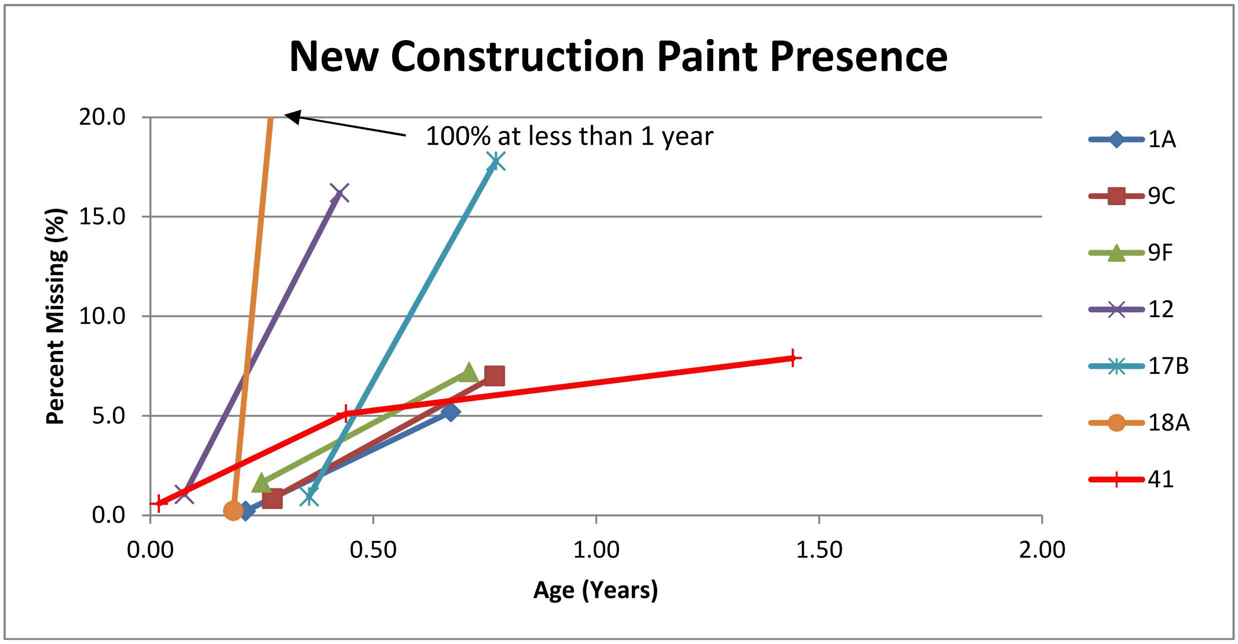


Figure 21. New construction paint presence (2010 - 2012 data).

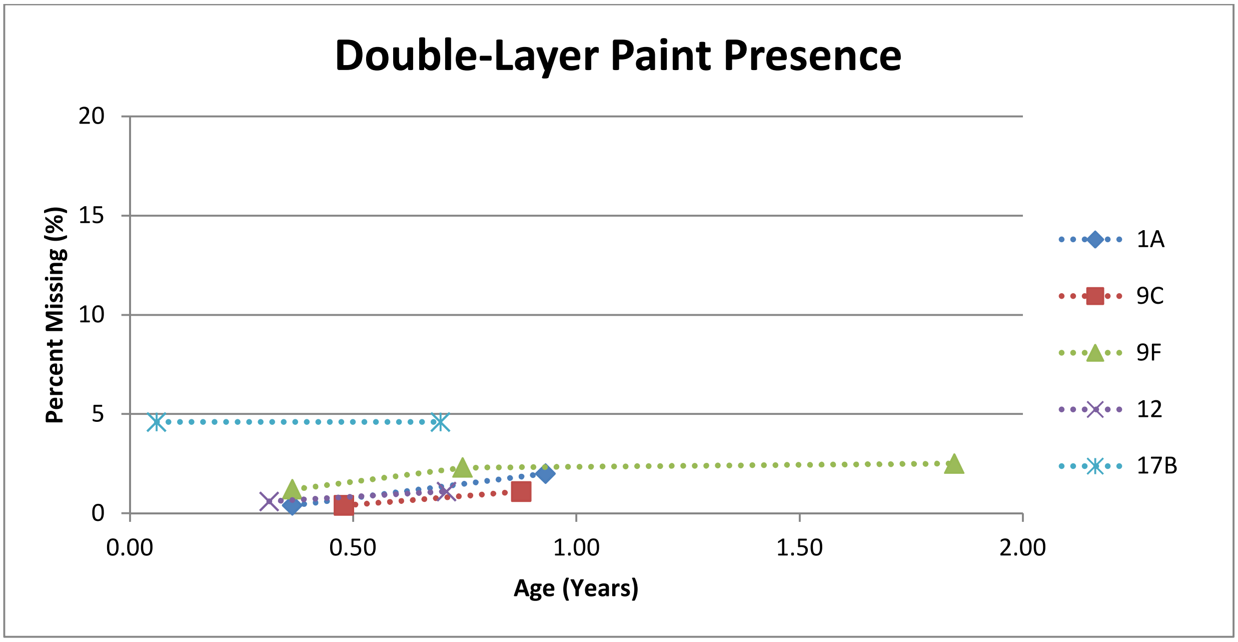


Figure 22. Double-layer paint presence (2011-2013 data).

Figure 23 compares the initial presence values of single and double-layered paint. Three out of five sites had a better presence (lower percentage missing) with a second coat. Paint-17B, however, had a much higher percentage missing than the other double-layer sites. This was due to poor restriping because the new layer was consistently less than 4" wide. Figure 24 compares the presence values after one winter. All five sites had a significantly lower percentage missing with a double layer of material. Again, the mild winter likely influenced the data of the double-layer paint.

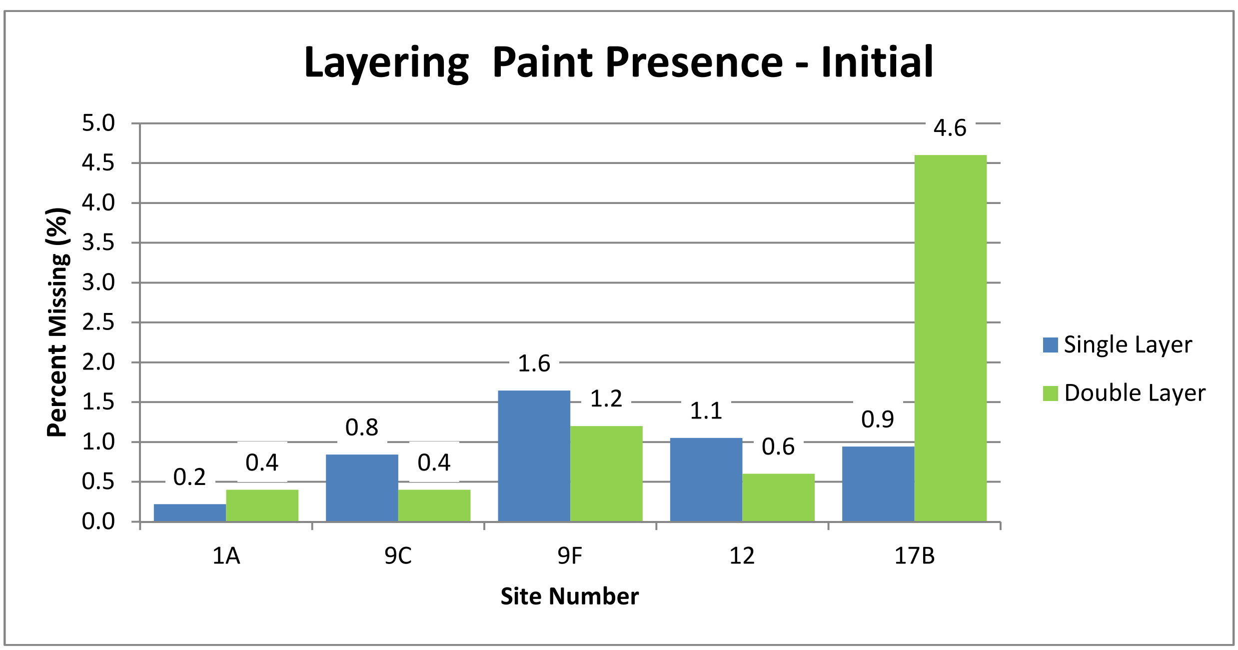


Figure 23. Initial paint presence for single and double layers.

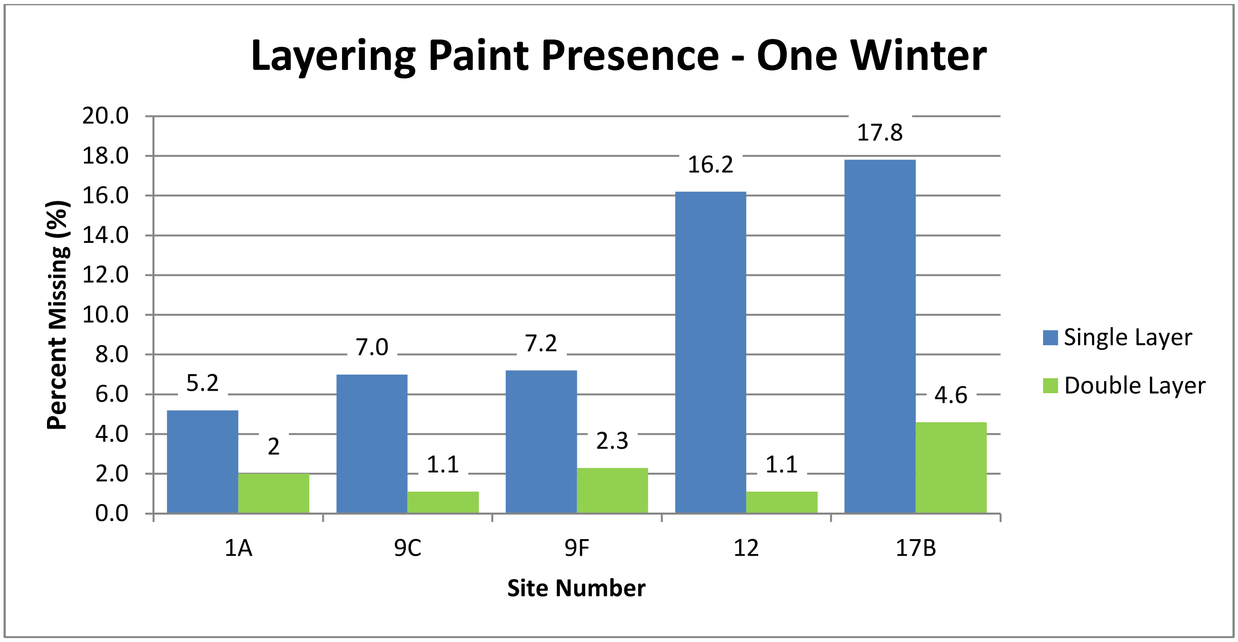


Figure 24. Paint presence for single and double layers after one winter.

The paint PMI values are graphed in Figure 25, Figure 26, and Figure 27. It is clear that both maintenance and new construction paint sites started to diverge from the maximum PMI of 100, but only Paint-18A dropped below the failure value of 60. The two sites tested beyond one winter showed very good retroreflectivity and presence values which correspond to high PMIs.

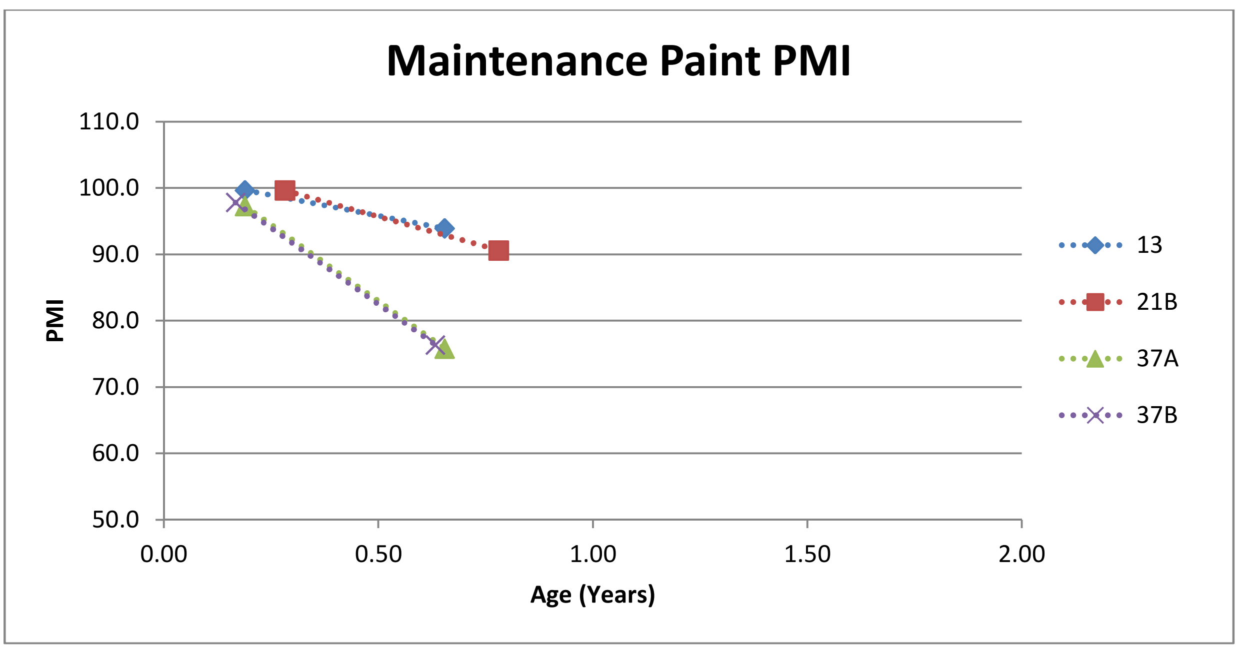


Figure 25. Maintenance paint Pavement Marking Index.

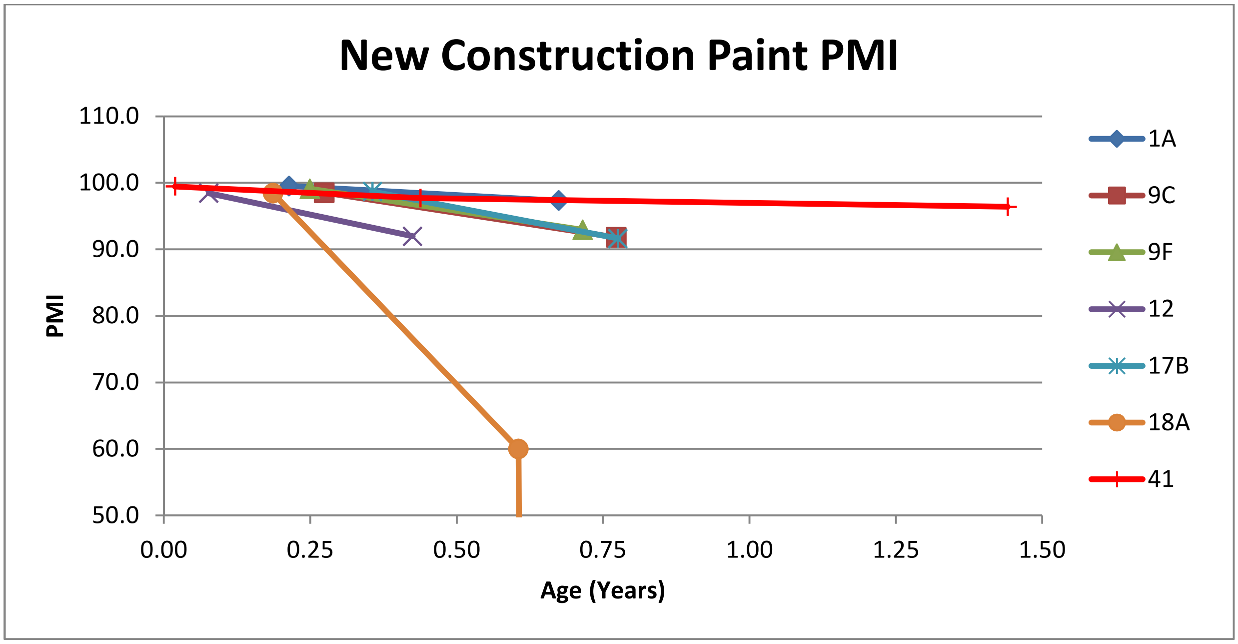


Figure 26. New construction paint Pavement Marking Index.

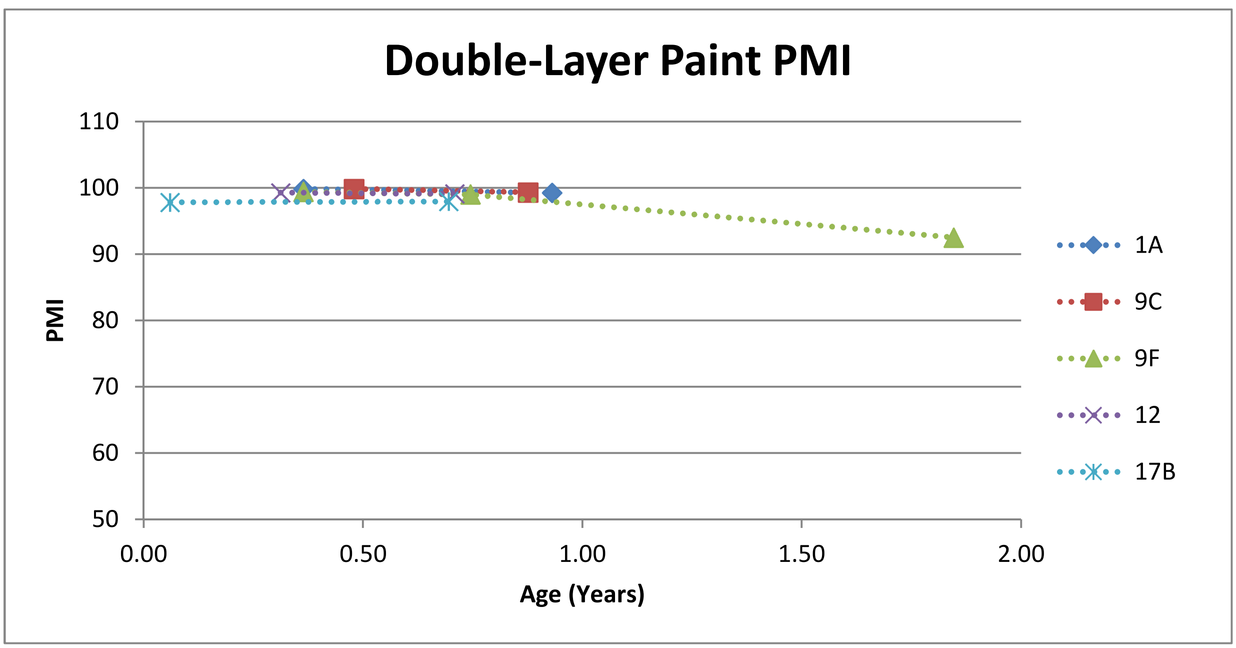


Figure 27. Double-layer paint Pavement Marking Index.

2.2. THERMOPLASTIC

The average retroreflectivity and presence measurements for the maintenance and new construction thermoplastic are listed in Table 7 and Table 8, respectively. Figure 28 and Figure 29 display the performance of thermoplastic sites' retroreflectivity over time.

The 2010 data is not included for Thermo-37A and 37C because they were restriped to correct an installation error. Therefore, 2011 is considered the initial testing for these sites. The initial and subsequent retroreflectivities for both sites are considered low despite the reapplication. These sites were treated with a spray-applied thermoplastic, which is often a thinner application than extruded thermoplastic. The material was applied to a rough asphalt surface because of the grinding method which was used to create a groove. The locations where pavement surface was flat and smooth yielded higher retroreflectivity readings compared with irregular or cracking surfaces. Besides these two sites, no other thermoplastic sites fell below 200 mcd/m^2/lux in this study.

Thermo-7A was unfortunately restriped before 2012 data collection. This small maintenance site was located at an intersection where the edge of the pavement experienced a considerable amount of cracking. Thermo-35B was restriped prior to 2013 data collection for unknown reasons.

Multiple thermoplastic sites exhibited an increase in retroreflectivity. The literature review conducted at the beginning of this study confirms that this trend has been observed in other thermoplastic research. The increase is due to the gradual exposure of beads embedded in the thermoplastic. The rate of bead exposure varies by ADT, plowing, and bead distribution. Therefore, the testing frequency for this study (one collection per year) was probably too low to capture this trend in all thermoplastic sites.

Thermo-41 is the thermoplastic site with the highest retroreflectivity with a value of 324 mcd/m^2/lux. This site is located in Zone 3 on an interstate with high ADT and multiple lanes in each direction. It is surface-applied; however, the pavement surface appears to slope downward toward the right edge joint which protected the marking from heavy plow contact. All four thermoplastic sites in Zone 3 and one site in Zone 1 had a retroreflectivity greater than 300 mcd/m^2/lux in 2012 and continued to perform well in 2013. Based on 2012 data, there are not any differences in retroreflectivity performance between maintenance and new construction sites. The remaining two original maintenance sites were restriped prior to 2013 testing.

Table 7. Maintenance Thermoplastic Data

Site #	ADT	Zone #	Pavement Type	Application	2010			2011			2012			2013		
					R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI
7A	1,800	1	HMA	Surface	363	0.5	100	321	1.9	99	**	**	**	**	**	**
7B	7,700	1	HMA	Surface	350	0.7	100	311	1.4	99	320	1.9	99	**	**	**
29	13,000	1	HMA	Surface	364	0.7	100	308	6.2	98	221	12.6	95	**	**	**
37A*	19,500	2	HMA	Recessed	-	-	-	219	1.1	98	154	3.9	90	158	17.0	86
37C*	28,800	2	HMA	Recessed	-	-	-	191	1.3	97	134	4.6	83	136	15.9	80

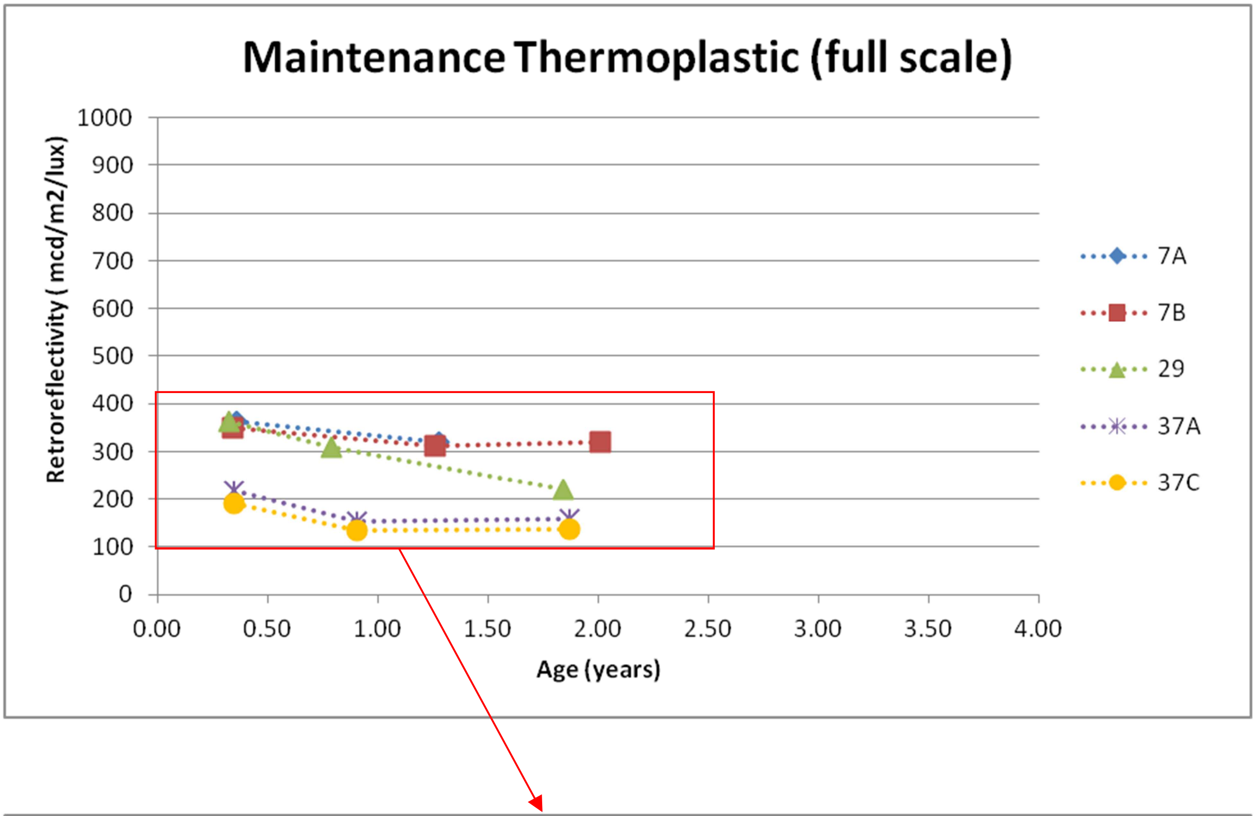
*Double Layer - Restriped between 2010 and 2011 data collection because of initial installation error

**No data because of restriping

Table 8. New Construction Thermoplastic Data

Site #	ADT	Zone #	Pavement Type	Application	2010			2011			2012			2013		
					R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI
3	7,500	1	HMA	Surface	469	0.9	100	326	14.6	95	220	20.2	92	210	28.7	88
9C	5,150	2	HMA	Surface	401	0.1	100	293	1.3	99	227	3.5	98	233	7.3	97
17B	2,800	3	HMA	Surface	415	0.1	100	377	1.4	100	377	4.0	99	283	11.8	96
17C	12,200	3	HMA	Surface	276	0.2	100	285	14.3	95	316	21.9	93	247	27.7	90
25	91,000	1	SMA	Surface	312	0.6	100	282	3.0	99	253	3.2	98	217	10.6	95
33B	12,000	2	HMA	Surface	201	0.4	98	176	0.4	95	200	1.8	97	223	2.9	98
35B	20,350	2	HMA	Surface	327	0.0	100	347	1.2	100	219	2.9	98	**	**	**
41	49,400	3	HMA	Surface	398	0.1	100	429	2.8	99	416	5.7	98	324	7.2	98
1B	22,400	3	Micro-Surface	Surface	306	0.2	100	363	1.9	99	302	2.4	99	275	5.4	98

**No data because of restriping



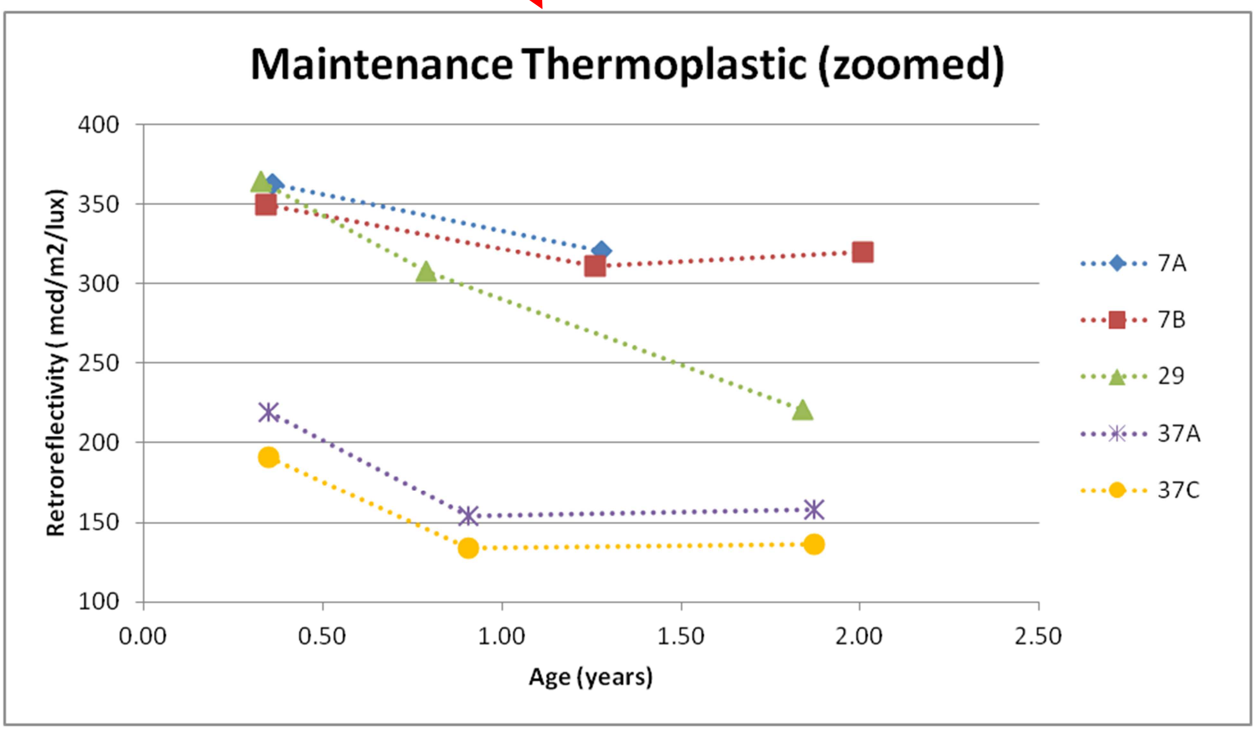


Figure 28. Maintenance thermoplastic retroreflectivity.

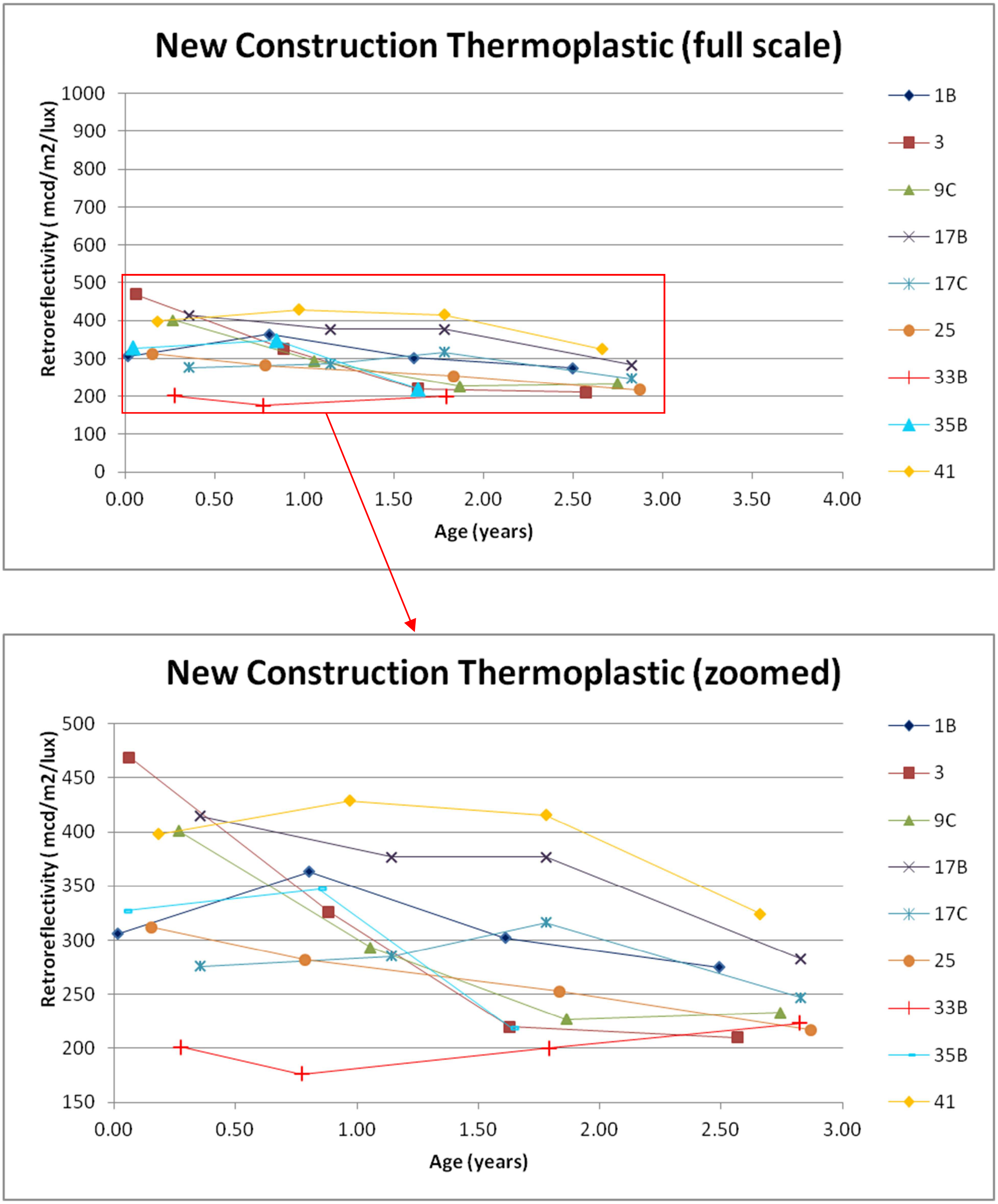


Figure 29. New construction thermoplastic retroreflectivity.

Figure 30 and Figure 31 show the thermoplastic presence values over time. Thermo-33B showed no deterioration of presence between 2010 and 2011 and continued to have the best presence performance of thermoplastic sites in 2012 and 2013. Thermo-3 and 17C showed the highest percentage of material missing at over 20%. Observation of these sites revealed that this deterioration was caused by plow damage.

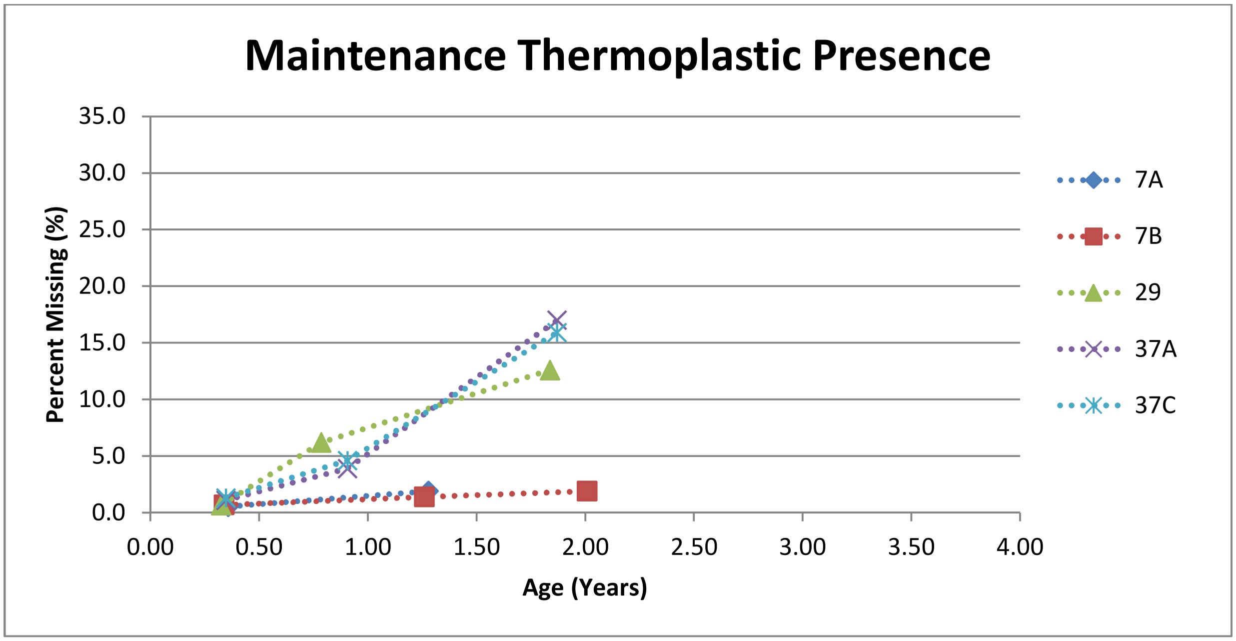


Figure 30. Maintenance thermoplastic presence.

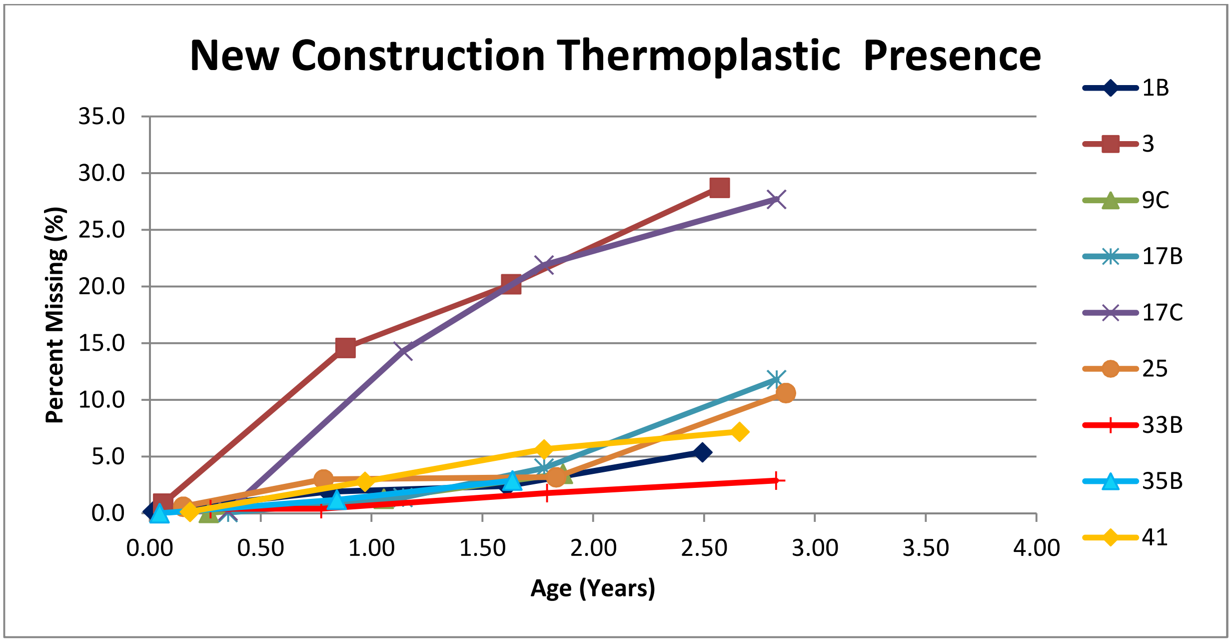


Figure 31. New construction thermoplastic presence.

The thermoplastic PMI values are graphed in Figure 32 and Figure 33. None of the extruded thermoplastic sites had a PMI less than 90 after two winters, but the Thermo-3 PMI fell to 88 after the third winter. The PMI for sprayed thermoplastic was lower than the PMI of extruded thermoplastic, but it remained at or above 80 after two winters.

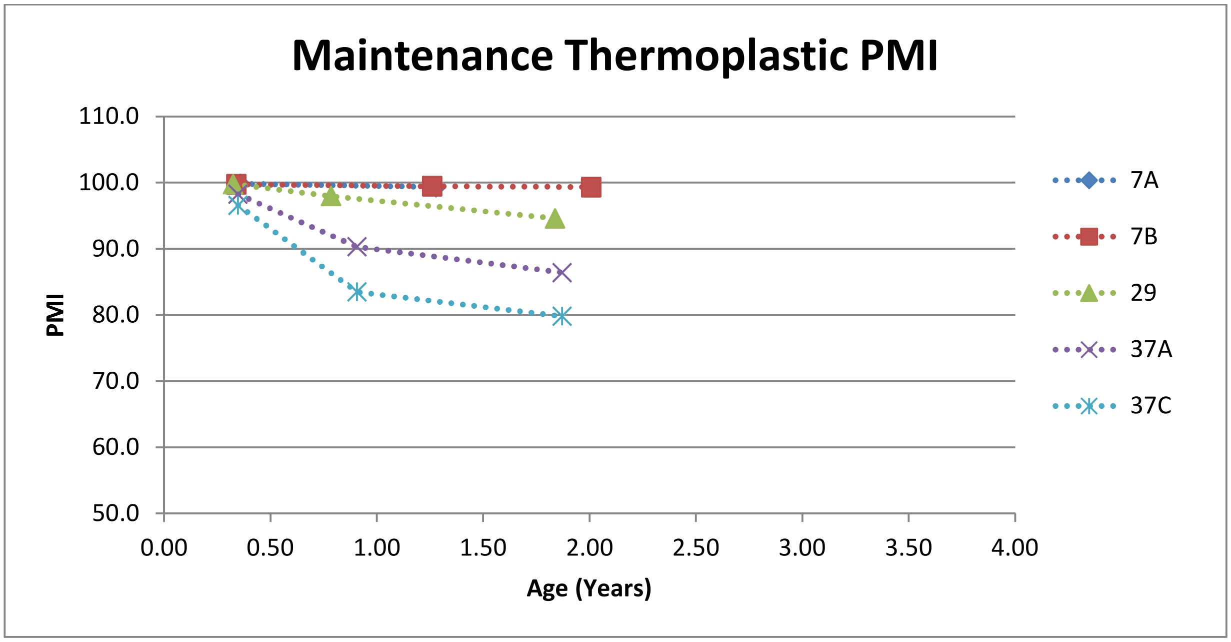


Figure 32. Maintenance thermoplastic PMI.

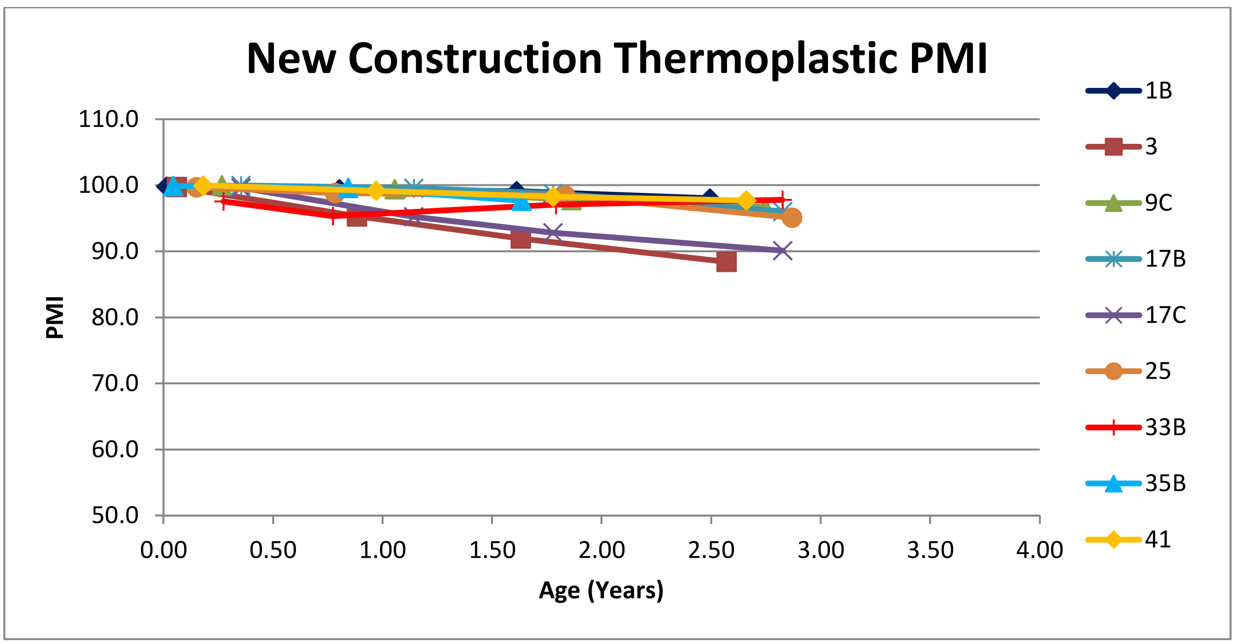


Figure 33. New construction thermoplastic PMI.

2.3. TAPE

The average retroreflectivity and presence measurements for tape placed on new construction are listed in Table 9. Figure 34 displays the retroreflectivity performance for all five tapes. Tape-23 was placed in 2009 on an older PCC pavement, but it was still included in the study because of the lack of tape sites on new PCC. This site performed very well because it is fully recessed. The raised surface geometry of the tape was less affected by traffic and plows. In addition, Tape-23 experienced fewer snow plow passes than the tapes further north because it is located in Zone 3. Despite the recent mild winter, Tape-23 experienced a large drop in retroreflectivity in 2012 and again in 2013.

Unlike the other tapes, Tape-10B showed almost no change in retroreflectivity from 2011 to 2012. It was protected from damage because it is inlaid. Inlay tapes are typically 50% embedded in the pavement while the HMA is still malleable. The average retroreflectivity of this site fell sharply in 2013 to 412 mcd/m^2/lux. The sites with the lowest retroreflectivity were Tape-1 and Tape-10A at 106 and 152 mcd/m^2/lux, respectively. Tape-10A is the only site located on a local road rather than a major highway. Tape-1 differs from the others because it (1) has a different raised surface pattern, as shown in Figure 35, (2) experiences a considerably higher ADT, and (3) is surface-applied. Tape-1 is the only tape placed entirely on the surface of the pavement.

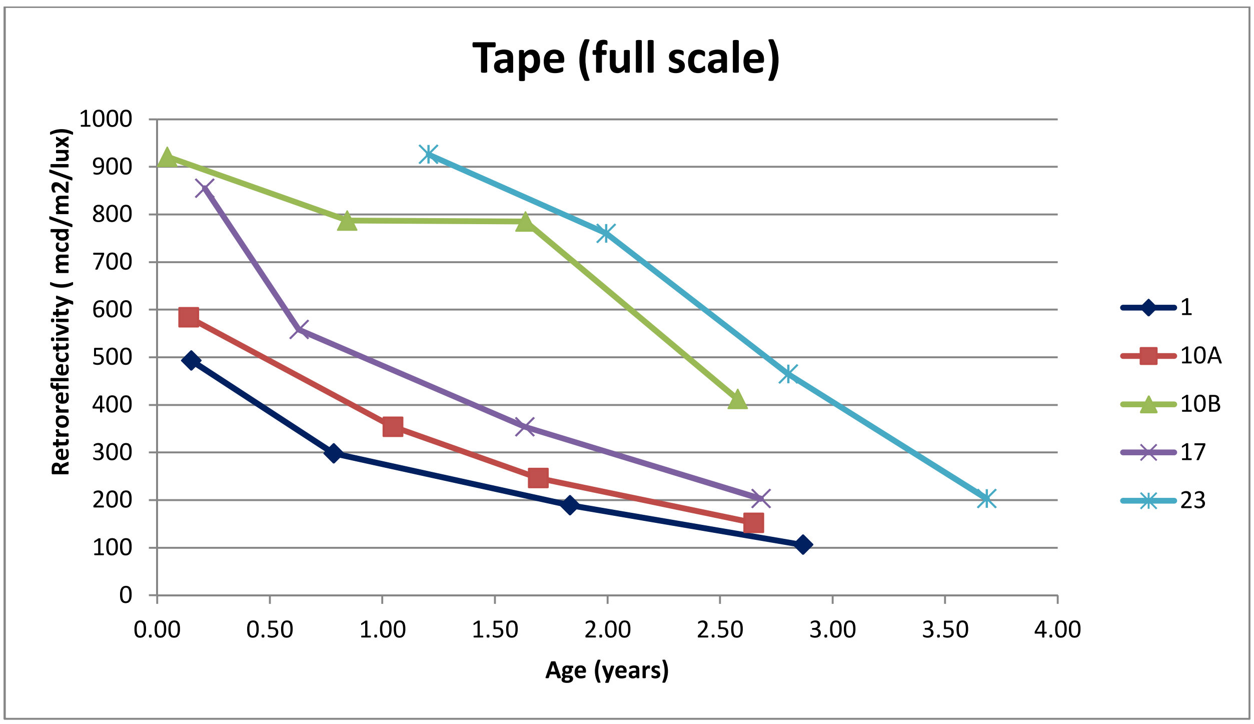


Figure 34. Tape retroreflectivity.

Table 9. Tape Data

Site #	ADT	Zone #	Pavement Type	Application	2010			2011			2012			2013		
					R_L ($mcd/m^2/lux$)	Presence (% missing)	PMI	R_L ($mcd/m^2/lux$)	Presence (% missing)	PMI	R_L ($mcd/m^2/lux$)	Presence (% missing)	PMI	R_L ($mcd/m^2/lux$)	Presence (% missing)	PMI
1	91,000	1	SMA	Surface	493	0.0	100	298	0.4	100	189	0.4	97	106	0.5	65
10A	5,000	2	HMA	Inlay	584	0.0	100	354	0.2	100	246	0.4	99	152	0.5	91
10B	20,350	2	HMA	Inlay	921	0.2	100	787	0.4	100	785	0.5	100	412	0.5	100
17	16,850-33,000	3	HMA	Inlay	855	0.2	100	558	0.3	100	354	0.6	100	203	1.9	97
23	31,500-56,100	3	PCC	Grooved	926	0.0	100	760	0.2	100	465	0.3	100	203	0.4	98

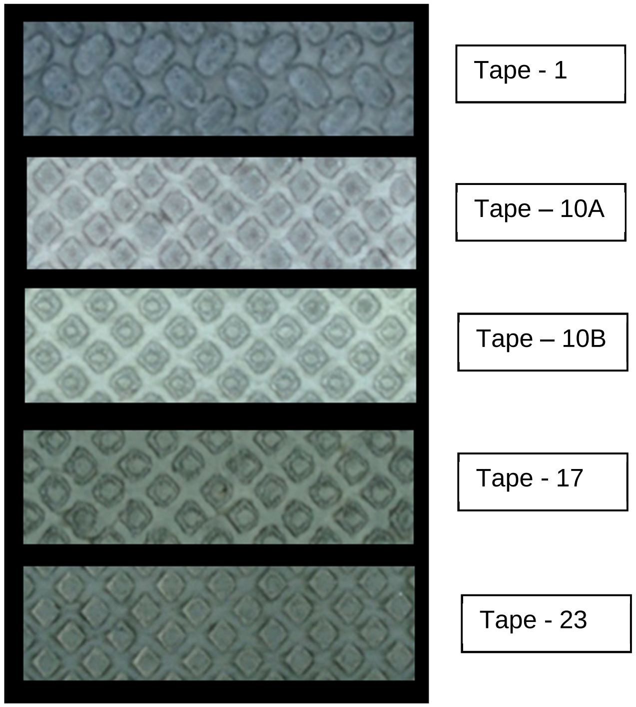


Figure 35. 2010 sample tape images showing differences in surface texture.

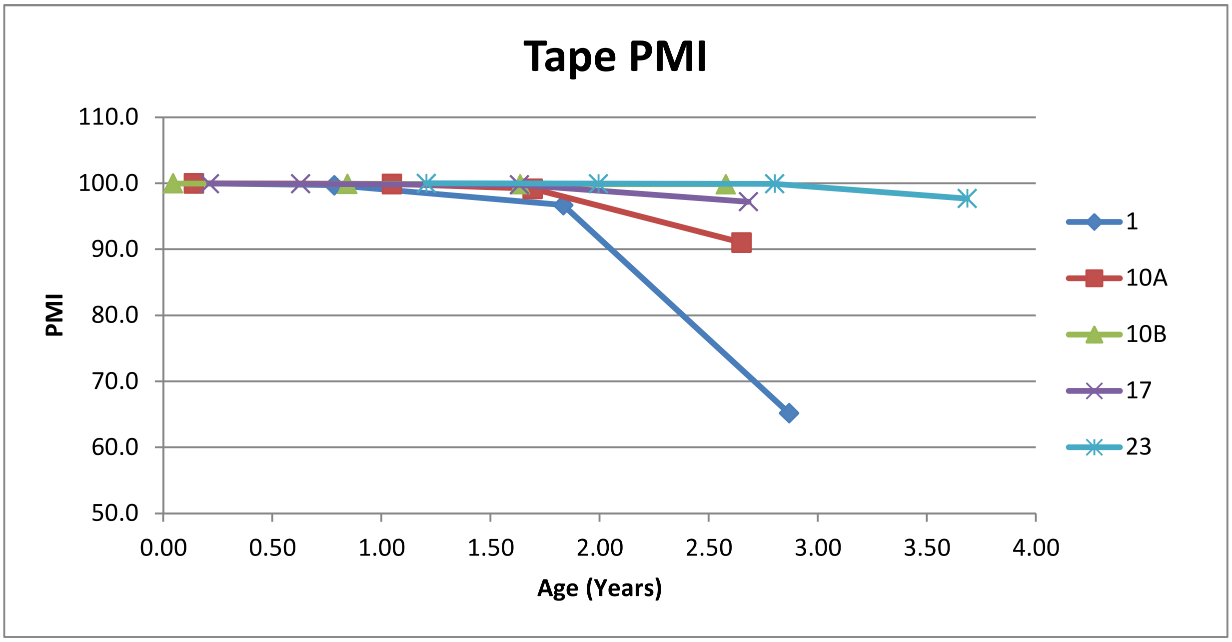


Figure 36. Tape Pavement Marking Index.

As expected, all tape sites showed very little deterioration of presence. The PMI values shown in Figure 36 reflect that the retroreflectivity for Tape-1 is very near failure and that Tape-10A seems to be following suit.

2.3.1 Illinois Tollway Tape

Listed in Table 10 are the Illinois Tollway research tape sites. Figure 37 shows that Tape-7 had a very high initial retroreflectivity before falling below 300 mcd/m^2/lux after only one year. The tape's manufacturer was aware that this tape's R_L deteriorates quickly and identified a flaw in the design of the raised elements. The design was changed, and the tape placed in this test section was no longer produced. Tape-8 showed an increase in retroreflectivity during the first 18 months after placement. This increase was likely due to the thin coating on the surface of the tape which prevented it from adhering to itself while it was rolled up. As traffic wore the coating off, the true surface became exposed. By age four, both Tape-7 and Tape-8 had an approximate retroreflectivity value of 150 mcd/m^2/lux, and at age six, neither tape showed any signs of impending failure. Tape-25 had the lowest retroreflectivity and was slightly above the failure threshold; however, it was restriped prior to 2012 data collection. The presence for this site was comparable to other tape sites before increasing to 13.6% missing at 5.09 years. Data tables are presented in Appendix B.

Table 10. Illinois Tollway New Construction Tape Site Information

Site Number	ADT	Zone Number	Pavement Type	Application
7	65,000	1	PCC	Grooved
8	65,000	1	PCC	Grooved
25	7,000	1	HMA	Surface

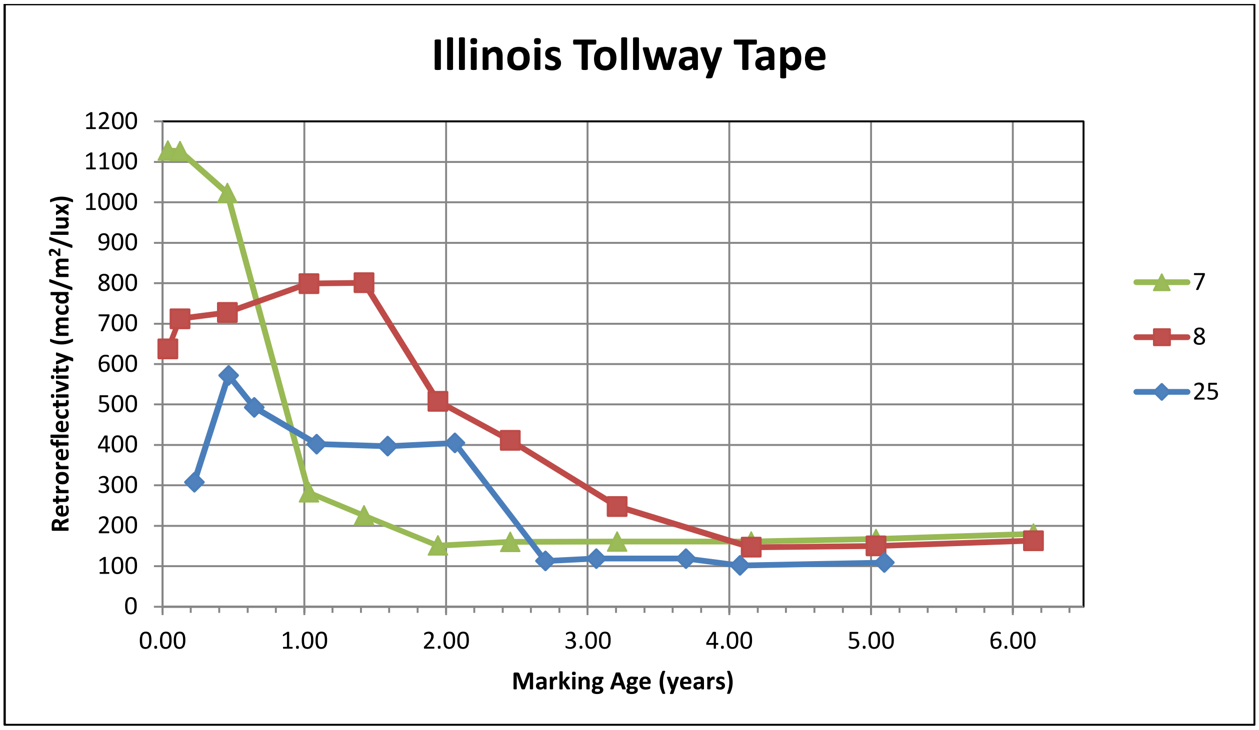


Figure 37. Illinois Tollway tape retroreflectivity data.

2.4. EPOXY

Because of material shortage and contract-related issues, none of the selected maintenance epoxy sites were placed in 2010. Epoxy-13AH was added in 2011 to become the only maintenance epoxy site included in this study. The average retroreflectivity and presence measurements for new construction and maintenance epoxy are listed in Table 11. Figure 38 displays retroreflectivity over time and Figure 39 displays presence over time.

Epoxy-9B had the lowest retroreflectivity and the highest percentage missing of the epoxy sites. It had an average retroreflectivity similar to that of Epoxy-9A, but Epoxy-9B's presence was deteriorating much faster.

Epoxy-13AH was placed over an existing marking. The retroreflectivity deteriorated over its first winter at the same rate as the new construction epoxy, but it fell below the new construction values after its second winter. Epoxy-13AH's presence was much better than the new construction values and it showed no change since the original data collection in 2011. This material proved durable; however, the glass beads were breaking away at a faster rate.

Figure 40 shows PMI values for the epoxy sites. The two new construction sites were following similar performance trends. The maintenance epoxy showed a similar trend initially, but later experienced a more rapid drop in performance because of an increasing loss in retroreflectivity.

Table 11. New Construction and Maintenance Epoxy Data

Site #	ADT	Zone #	Pavement Type	Application	2010			2011			2012			2013		
					R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI
9A	5,000	2	HMA	Surface	527	0.3	100	203	5.0	96	183	8.2	94	169	10.6	91
9B	9,400	2	HMA	Surface	401	0.9	100	194	8.2	95	177	14.7	91	163	23.4	85
13AH*	2,150-5,300	2	HMA	Surface	-	-	-	490	1.3	100	220	1.4	98	140	1.4	87

*Maintenance site

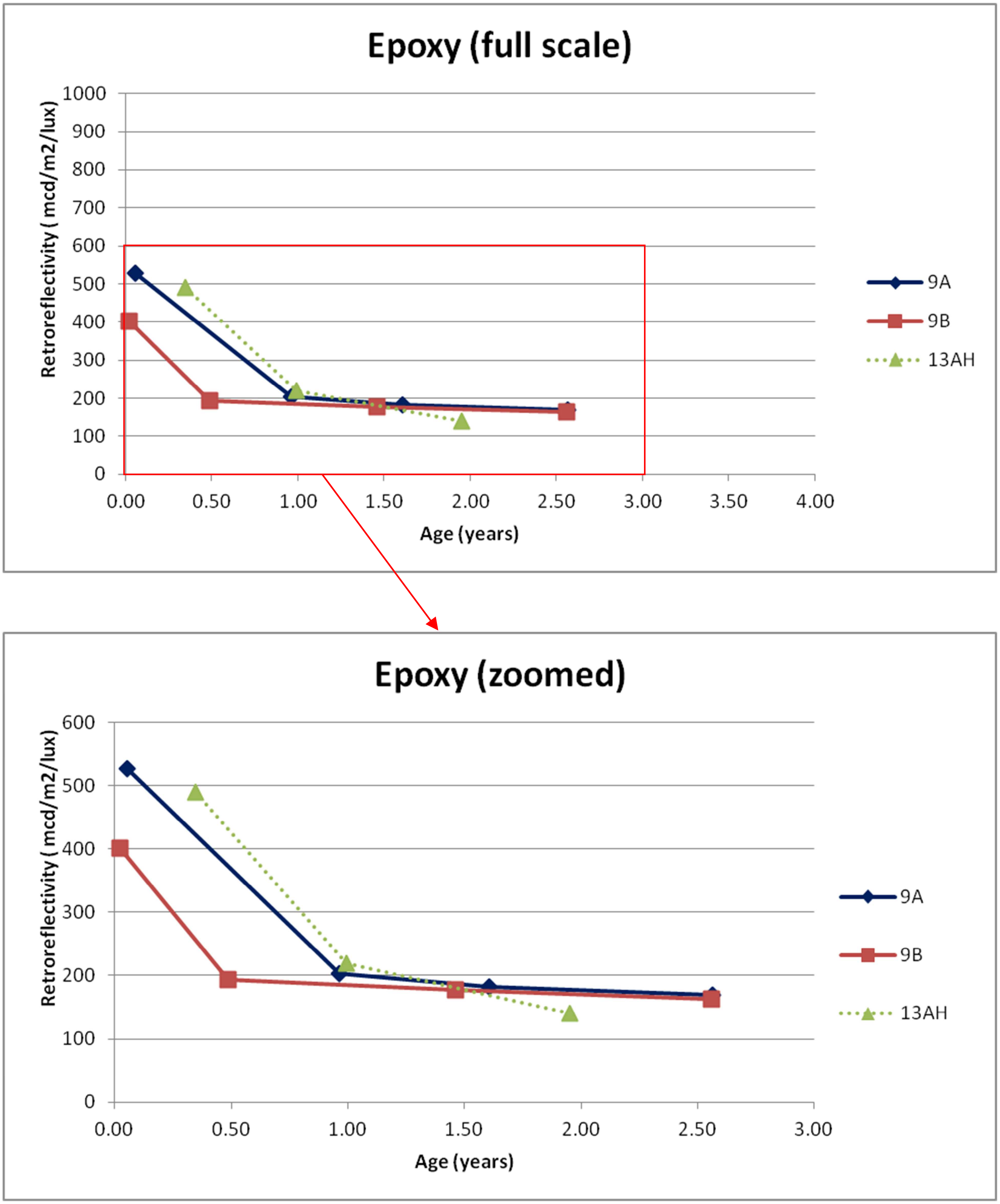


Figure 38. Epoxy retroreflectivity.
Note: New construction sites are solid lines. Maintenance sites are dotted lines.

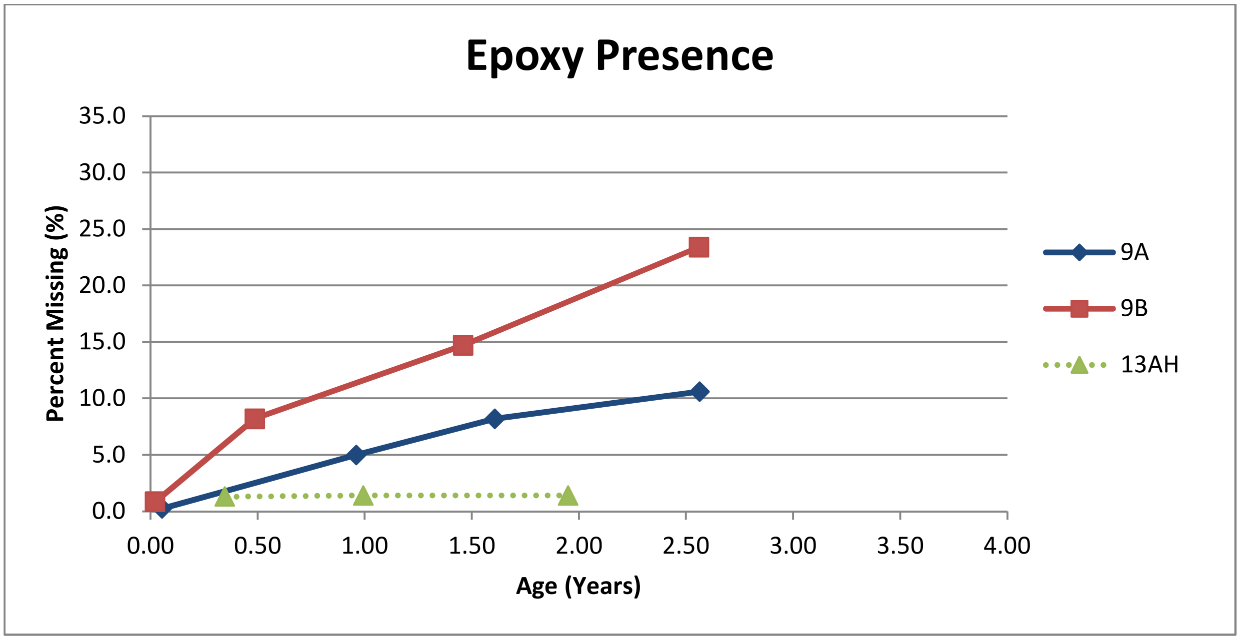


Figure 39. Epoxy presence.
Note: New Construction sites are solid lines. Maintenance sites are dotted lines.

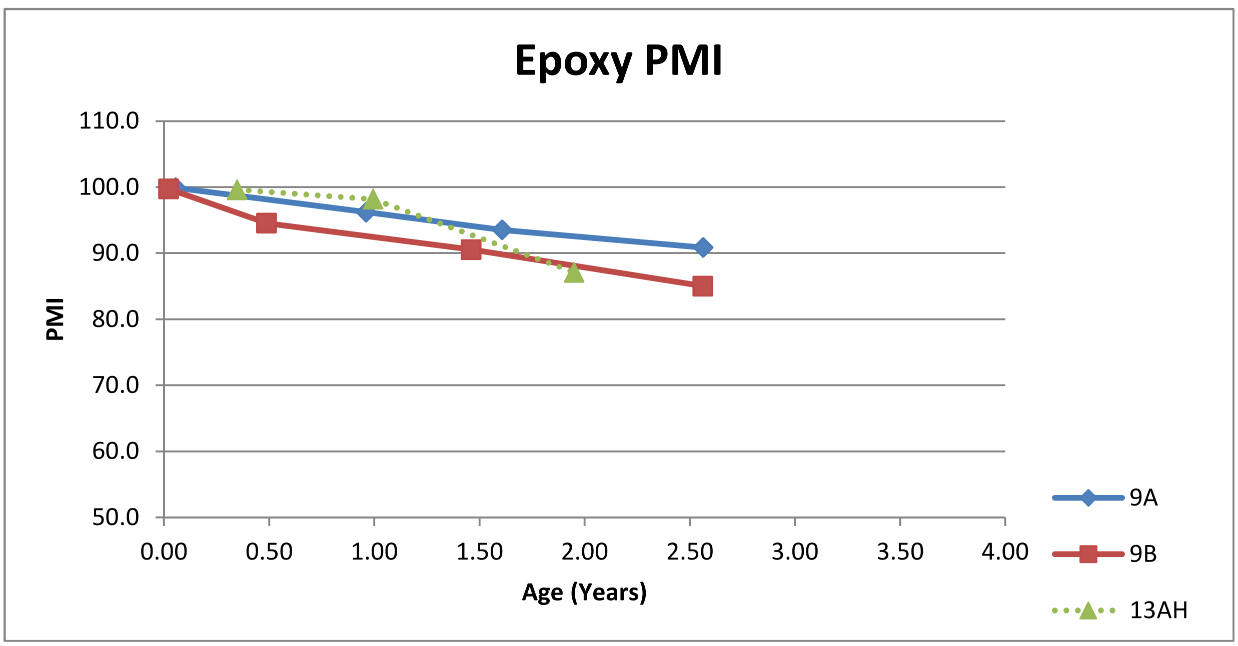


Figure 40. Epoxy Pavement Marking Index.
Note: New Construction sites are solid lines. Maintenance sites are dotted lines.

2.4.1 Illinois Tollway Epoxy

Listed in Table 12 are the Illinois Tollway research epoxy sites. Epoxy-1, a surface application, had a noticeably lower retroreflectivity. At three years of age, it was the only epoxy to fall below 100 mcd/m^2/lux. The other epoxy sites had higher initial retroreflectivity and continued to perform well in high ADT locations. Figure 41 presents the sites' retroreflectivity performance over time. Epoxy-1 also had the largest percentage of missing material, which reached 25.2% at 3.69 years and increased to 63.8% at 5.75 years. Epoxy-4 had the best performing presence of 3.3% missing at 6.15 years.

Table 12. Illinois Tollway New Construction Epoxy Site Information

Site Number	ADT	Zone Number	Pavement Type	Application
1	7,000	1	HMA	Surface
2A	25,000	1	SMA	Recessed
2B	65,000	1	HMA	Recessed
4	60,000	1	PCC	Recessed

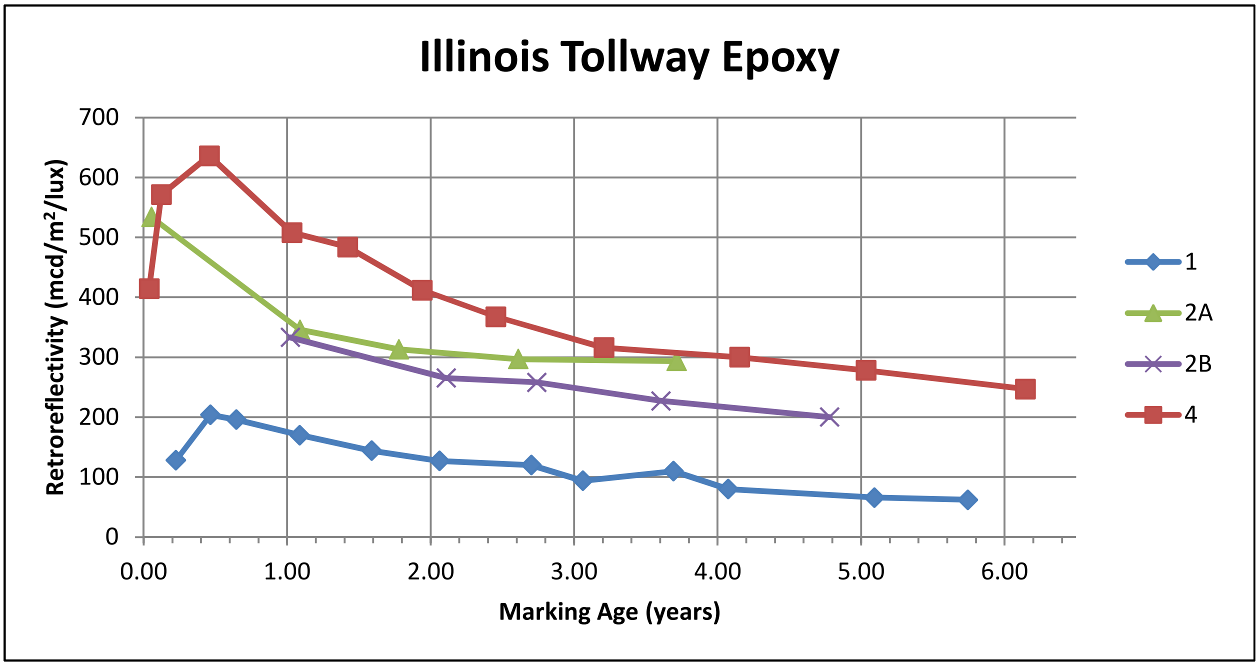


Figure 41. Illinois Tollway epoxy retroreflectivity data.

2.5. POLYUREA

The average retroreflectivity and presence measurements for the maintenance polyurea and new construction polyurea are listed in Table 13 and Table 14, respectively. The average retroreflectivity in 2013 ranged from 62 to 500 mcd/m^2/lux. Figure 42 displays the retroreflectivity performance, and Figure 43 displays the presence performance.

Poly-3 displayed a high initial retroreflectivity and increased to a slightly higher reading in 2011. The initial testing of this site was performed three days after it was installed. Therefore, it's possible that loose, excess beads had not yet been swept away by traffic or weather. Only embedded beads create the correct refraction to return light to the driver's eyes. Retroreflectivity values have remained high since 2011, which indicates that the markings were well-installed.

One of the oldest polyurea sites, Poly-13, had the lowest retroreflectivity throughout the study. Both Poly-13 and Poly-15 had a retroreflectivity below 100 mcd/m^2/lux in 2013. These markings are maintenance sites and are located in high ADT locations. The deterioration of markings was primarily caused by plows because the bright white surface was scraped away to reveal a grey layer that contained no beads. The grey surface is a lower layer of the marking and not material from a previous installation. Poly-21 also started to exhibit this type of deterioration, but it was restriped before 2013 data collection.

Poly-19D had the highest percentage missing.. Poly-19D is a new construction site; however, it was apparent in 2010 that this material was "recapped", which means that a second layer was placed on top of the initial layer in the same year. The original layer was probably installed when concrete curing compound was present on the pavement because the marking did not adhere to the pavement and started chipping off. The second layer was installed on top of the material that had not yet chipped off. As the original layer continued to separate from the pavement, the second layer was removed with it. Had this marking been installed correctly, it would have performed much better because its retroreflectivity was 269 mcd/m^2/lux in 2013.

Table 13. Maintenance Polyurea Data

Site #	ADT	Zone #	Pavement Type	Application	2010			2011			2012			2013		
					R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI
6	17,700-30,300	1	HMA	Recessed	321	0.3	100	241	0.7	99	**	**	**	**	**	**
13	28,800-54,300	2	HMA	Surface	305	0.5	100	88	2.6	59	72	5.1	57	62	15.8	52
15	20,000+	2	PCC	Surface	460	0.1	100	129	1.1	82	115	1.3	73	99	1.8	59
21	13,500	2	HMA	Surface	318	0.8	100	216	1.9	98	176	6.5	93	**	**	**

**No data because of restriping

Table 14. New Construction Polyurea Data

Site #	ADT	Zone #	Pavement Type	Application	2010			2011			2012			2013		
					R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI	R_L (mcd/m^2/lux)	Presence (% missing)	PMI
3	22,100	1	PCC	Surface	602	0.3	100	620	0.9	100	618	1.0	100	500	1.6	100
19D	2,350	3	PCC	Surface	345	1.4	100	319	12.4	96	314	19.5	94	269	25.7	91

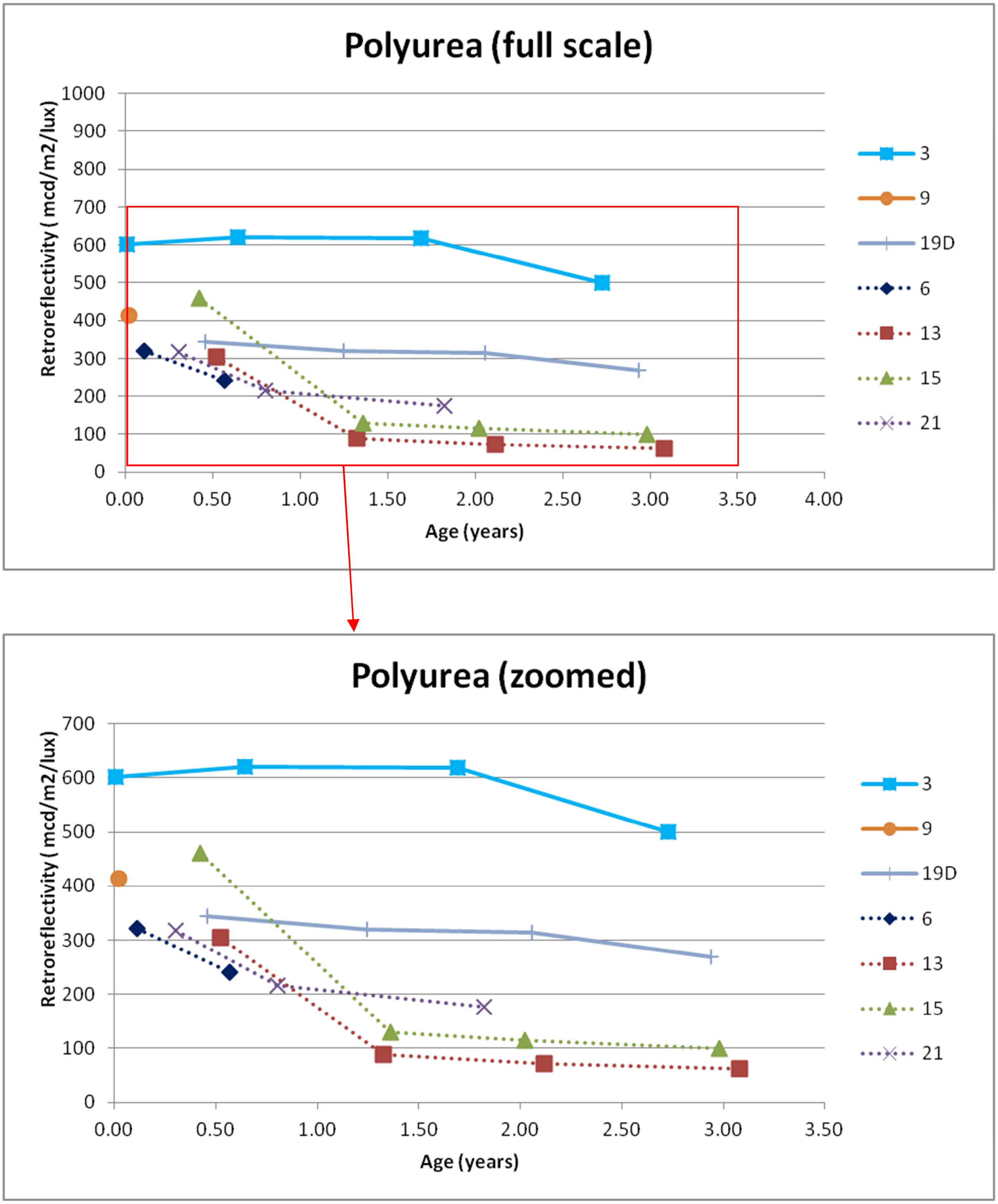


Figure 42. Polyurea retroreflectivity.
Note: New construction sites are solid lines. Maintenance sites are dotted lines.

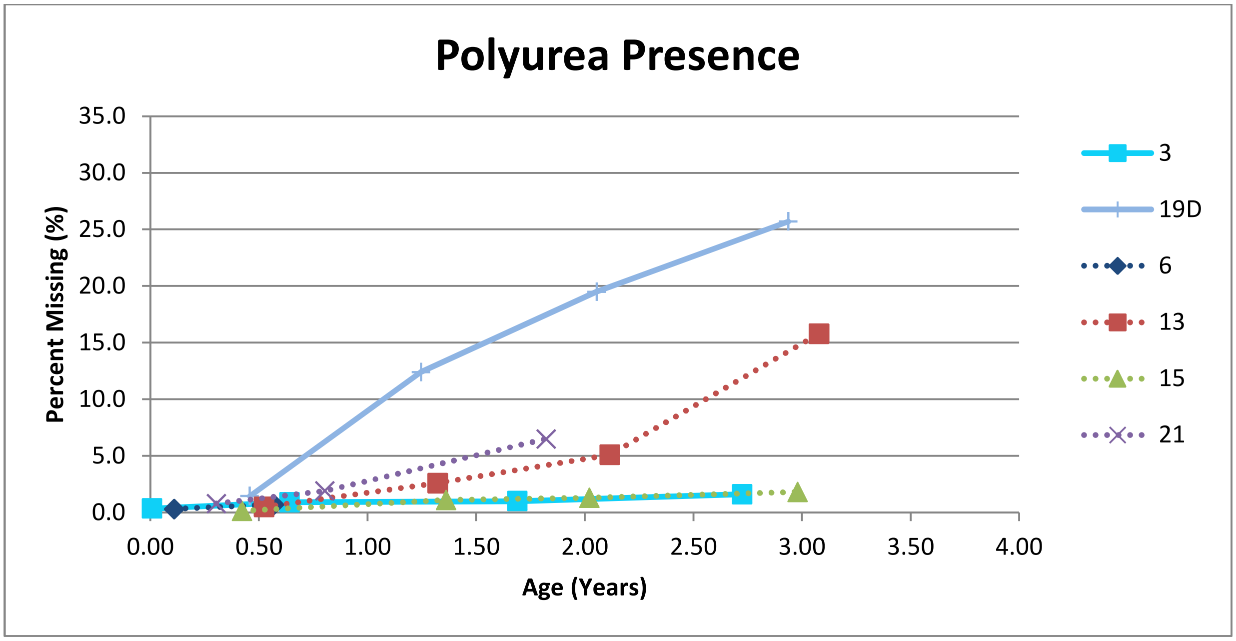


Figure 43. Polyurea presence.
Note: New construction sites are solid lines. Maintenance sites are dotted lines.

Figure 44 displays the polyurea PMI values and clearly shows that Poly-13 and Poly-15 failed as the PMI fell below 60. The PMI values of Poly-21 and 19D showed similar performance in 2012 although both had different retroreflectivity and presence values. Poly-3 had a PMI of 100 almost three years after installation.

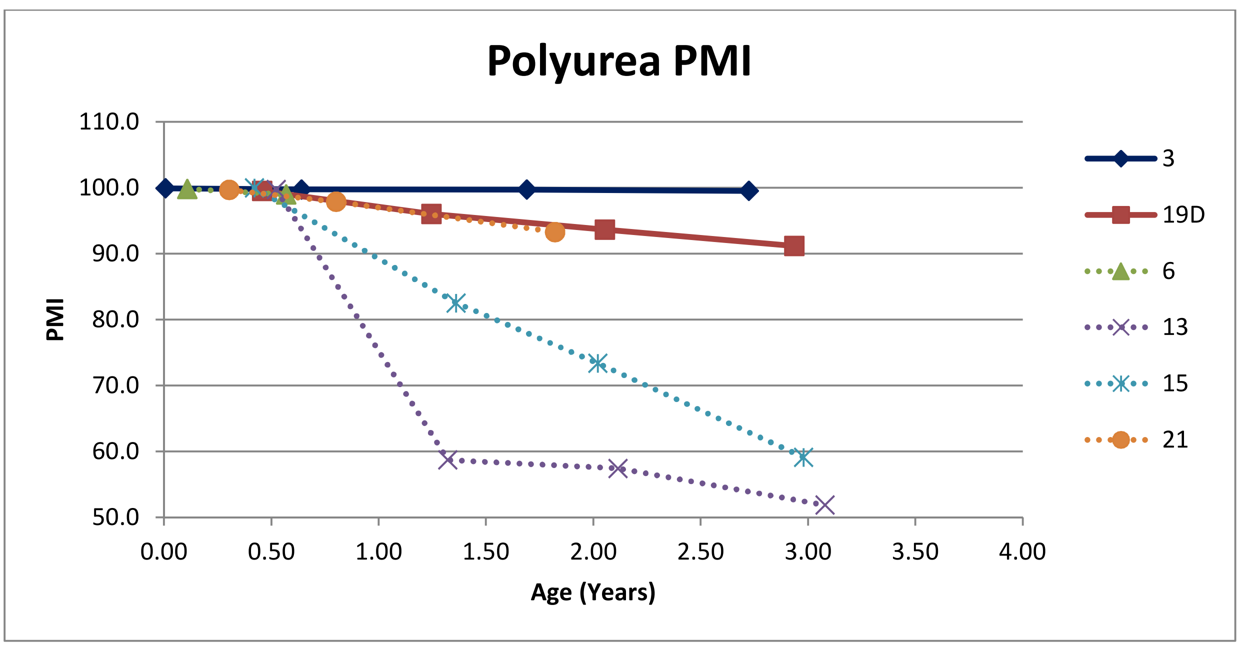


Figure 44. Polyurea Pavement Marking Index.
Note: New construction sites are solid lines. Maintenance sites are dotted lines.

In early March 2011, it was noticed that several sections of the northbound lines at the Poly-6 site had significantly deteriorated. This HMA surface was 8 years old when the markings were placed in the fall of 2010, and the pavement was already exhibiting some distress at the longitudinal joints. Figure 45 shows an example of marking and pavement deterioration. Polyurea might have accelerated pavement deterioration; however, some sections of longitudinal joints that did not have markings exhibited similar deterioration. The loss of pavement and marking material was so great that repairs had to be made and the site was restriped. This site was the only recessed polyurea and was not tested after 2011.

Figure 45. March 2011 photo of Poly-6 site (northbound right edge line).

2.5.1 Illinois Tollway Polyurea

Table 15 lists Illinois Tollway research polyurea sites. Figure 46 shows the sites' retroreflectivity over time. Poly-1B was the only surface polyurea site tested on the Illinois Tollway mainline; the site's retroreflectivity failed at about 3.69 years. The other sites are recessed, have much higher initial retroreflectivities, and continue to perform well in high ADT locations. Poly-2A and Poly-26 had the highest retroreflectivity of the polyurea sites. Both sites are recessed on asphalt and are from a lower ADT (7,000) location. Poly-25B was the only short set of data because the site was accidentally restriped early in the study. Poly-1B, 2A, and 25 are no longer being tested because they were restriped prior to 2012 data collection. The presence of Poly-1B was the worst of the tollway sites; it was missing 28.6% material by 3.69 years, which rose to 63.8% at 5.75 years. The best performing polyurea for presence was Poly-4A, which showed only 5.6% missing at 6.15 years.

Table 15. Illinois Tollway New Construction Polyurea Site Information

Site Number	ADT	Zone Number	Pavement Type	Application
1B	7,000	1	HMA	Surface
2A	7,000	1	HMA	Recessed
4A	65,000	1	PCC	Recessed
4B	65,000	1	PCC	Recessed
4C	65,000	1	PCC	Recessed
25A	65,000	1	PCC	Recessed
25B	65,000	1	PCC	Recessed
26	7,000	1	HMA	Recessed

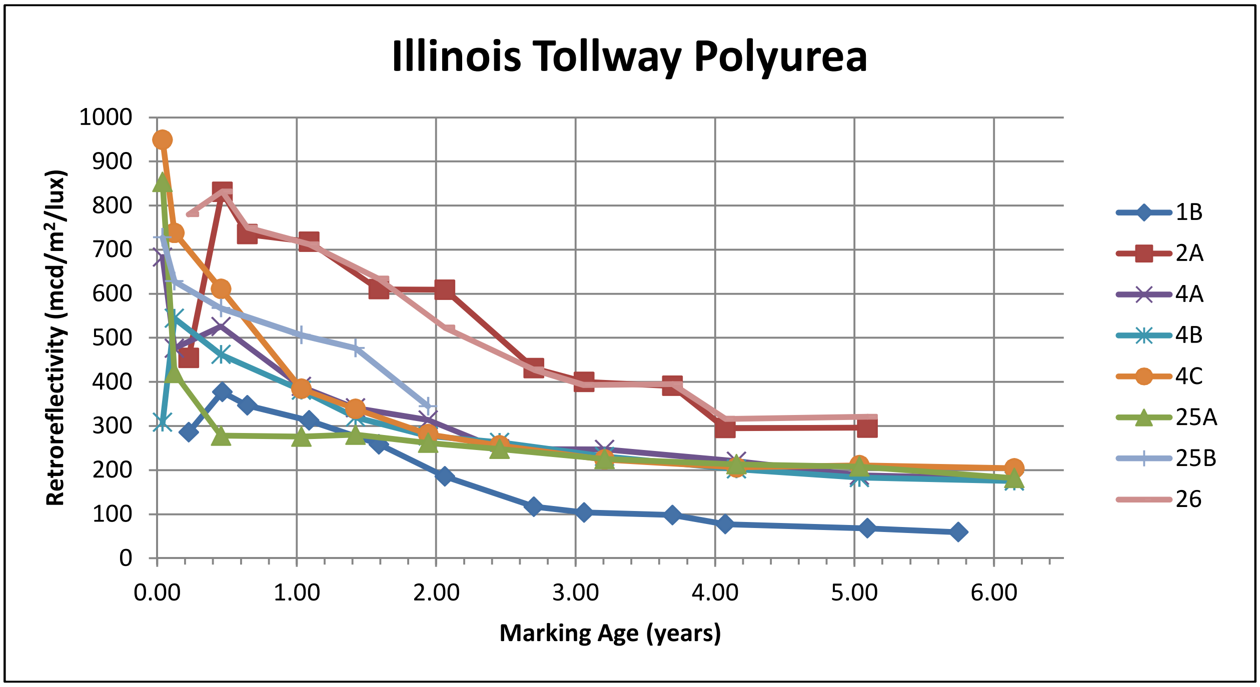


Figure 46. Illinois Tollway polyurea retroreflectivity data.

2.6. URETHANE

In addition to the nine urethane sites installed in 2010, three maintenance sites were added in 2011. The installation of Urethane-16F was scheduled in 2010 but was delayed. Urethane-6 and 8 were added to other test sites after their installation. The average retroreflectivity and presence measurements for the maintenance and new construction urethane sites are listed in Table 16 and Table 17, respectively. The graphs of retroreflectivity over time are found in Figure 47 and Figure 48.

The initial urethane retroreflectivity average for all sites was 486 mcd/m^2/lux. Urethane-14G represented the lowest initial retroreflectivity at 250 mcd/m^2/lux. The low reflectivity was likely due to poor bead embedment at installation. Three of the four new construction sites, all surface-applied, experienced a rapid drop in retroreflectivity in the first winter before beginning to plateau for the remainder of the study. The 2013 data collection showed four sites between 159 and 130 mcd/m^2/lux.

Urethane-10 had the highest retroreflectivity of the sites installed in 2010. The data showed an unusual increase in retroreflectivity in 2011 which was probably caused by the moisture that was present on pavement at the time of first data collection. Moisture on markings reduced the retroreflectance; therefore, Urethane-10's initial reading was likely higher than 509 mcd/m^2/lux.

Urethane-6 and Urethane-8 showed the best performance among the maintenance sites. The same marking material was placed on both asphalt and concrete pavements in order to observe the performance of urethane on different pavements under the same weather and traffic conditions. The retroreflectivity of Urethane-8, urethane on PCC, was approximately 27 mcd/m^2/lux higher each year. These sites, along with Urethane-10, are recessed and expected to continue to perform well.

Table 16. Maintenance Urethane Data

Site #	ADT	Zone #	Pavement Type	Application	2010			2011			2012			2013		
					R_L (mcd/m²/lux)	Presence (% missing)	PMI	R_L (mcd/m²/lux)	Presence (% missing)	PMI	R_L (mcd/m²/lux)	Presence (% missing)	PMI	R_L (mcd/m²/lux)	Presence (% missing)	PMI
7B	13,000	1	PCC	Surface	478	0.3	100	367	0.9	100	208	3.6	97	**	**	**
7C	10,200	1	PCC	Surface	497	0.1	100	290	1.4	99	253	1.6	99	236	3.2	98
13E	9,700-14,600	2	HMA	Surface	513	0.3	100	391	0.6	100	323	1.6	99	252	2.3	99
14G	25,000-27,700	2	HMA	Recessed	250	0.9	99	160	10.6	89	160	12.3	89	148	24.5	81
15	12,000+	2	PCC	Surface	511	0.5	100	317	2.2	99	293	6.8	98	279	7.1	98
16F	14,700-17,200	2	PCC	Recessed	-	-	-	381	0.2	100	285	1.6	99	235	5.3	97
6	11,600	1	HMA	Recessed	-	-	-	569	0.4	100	478	2.1	99	404	2.1	99
8	11,600	1	PCC	Recessed	-	-	-	593	0.1	100	510	0.8	100	429	3.9	99

**No data because of restriping

Table 17. New Construction Urethane Data

Site #	ADT	Zone #	Pavement Type	Application	2010			2011			2012			2013		
					R_L (mcd/m²/lux)	Presence (% missing)	PMI	R_L (mcd/m²/lux)	Presence (% missing)	PMI	R_L (mcd/m²/lux)	Presence (% missing)	PMI	R_L (mcd/m²/lux)	Presence (% missing)	PMI
3	8,900	1	PCC	Surface	481	2.2	99	178	9.4	93	147	13.1	85	159	34.9	80
9C	7,700	2	HMA	Surface	530	0.6	100	150	10.3	87	141	13.9	83	130	18.4	76
9D	32,800	2	HMA	Surface	609	0.4	100	266	3.7	98	216	4.6	97	158	9.1	89
10	11,800	2	HMA	Recessed	420	0.5	100	509	0.8	100	379	1.1	100	310	2.9	99

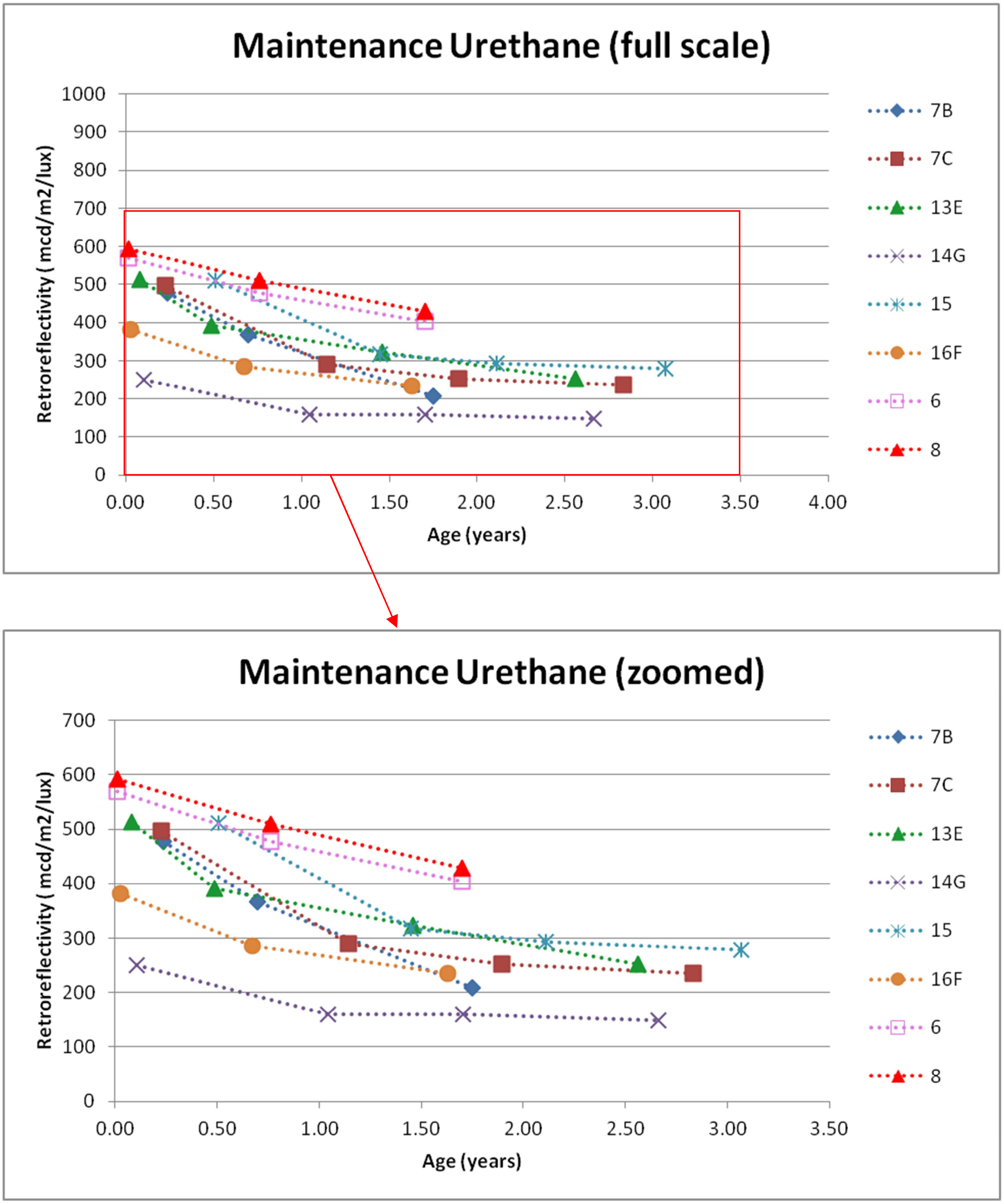


Figure 47. Maintenance urethane retroreflectivity.

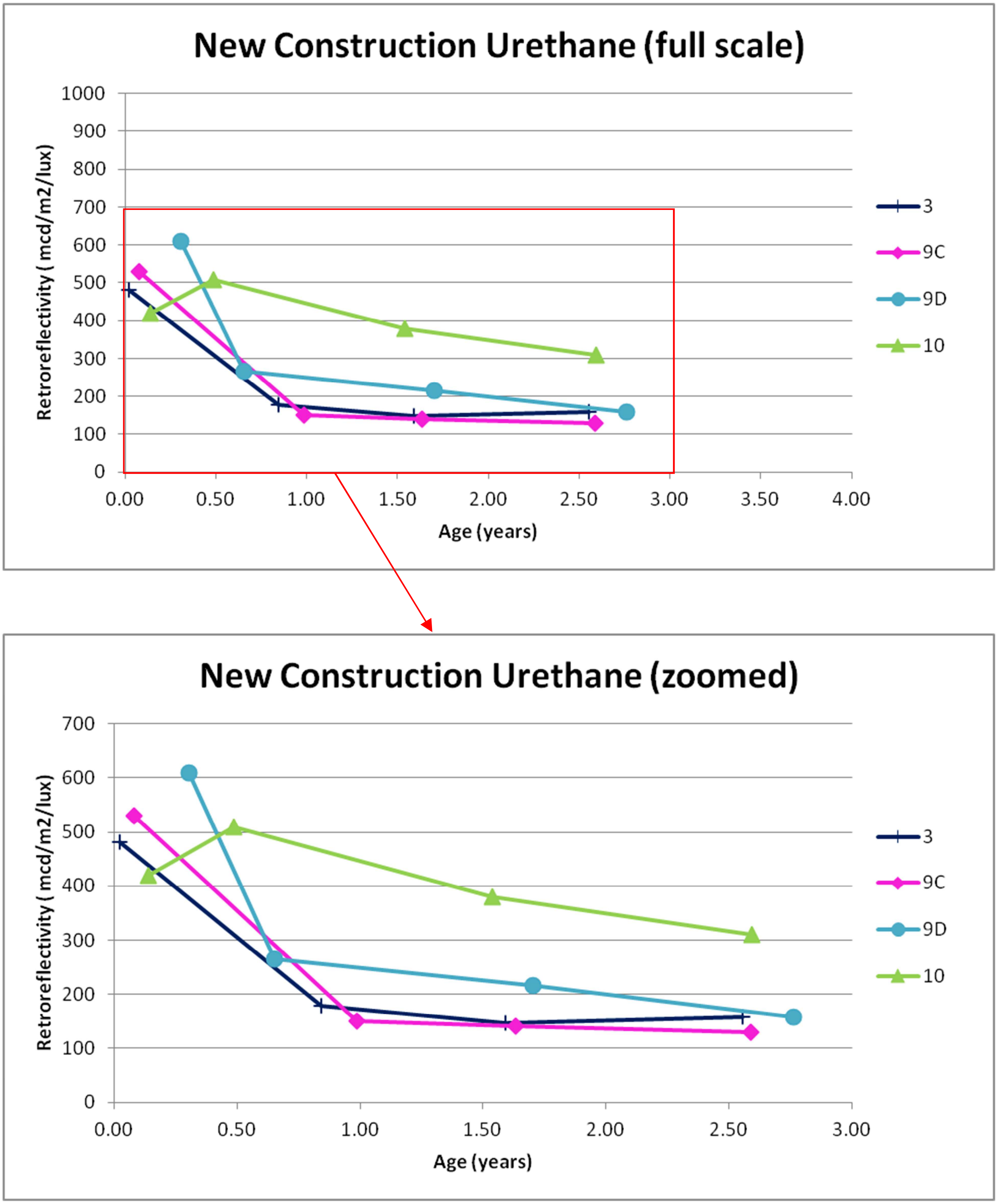


Figure 48. New construction urethane retroreflectivity.

Figure 49 and Figure 50 display the performance of urethane sites' presence. Initially, Urethane-3 had the highest percentage of missing marking because of the tining in the concrete, which caused indents in the stripe that collect particulates. It exhibited deterioration in the form of large pieces of marking chipping away and the percent missing has continued to increase with a large jump after the 2012-2013 winter.

Urethane-14G and 9C also had high percentages of missing material. The presence deterioration of Urethane-14G is associated with the pavement surface deterioration, and cracks in the marking suggest that this will continue to get worse as the pavement and marking age. Urethane-9C was worn down by plowing.

Urethane-15 showed a noticeable increase in the rate of presence deterioration from 2011 to 2012. This was likely due to increased construction traffic as slab replacement and other maintenance was performed on the pavement. The 2013 presence supports this theory.

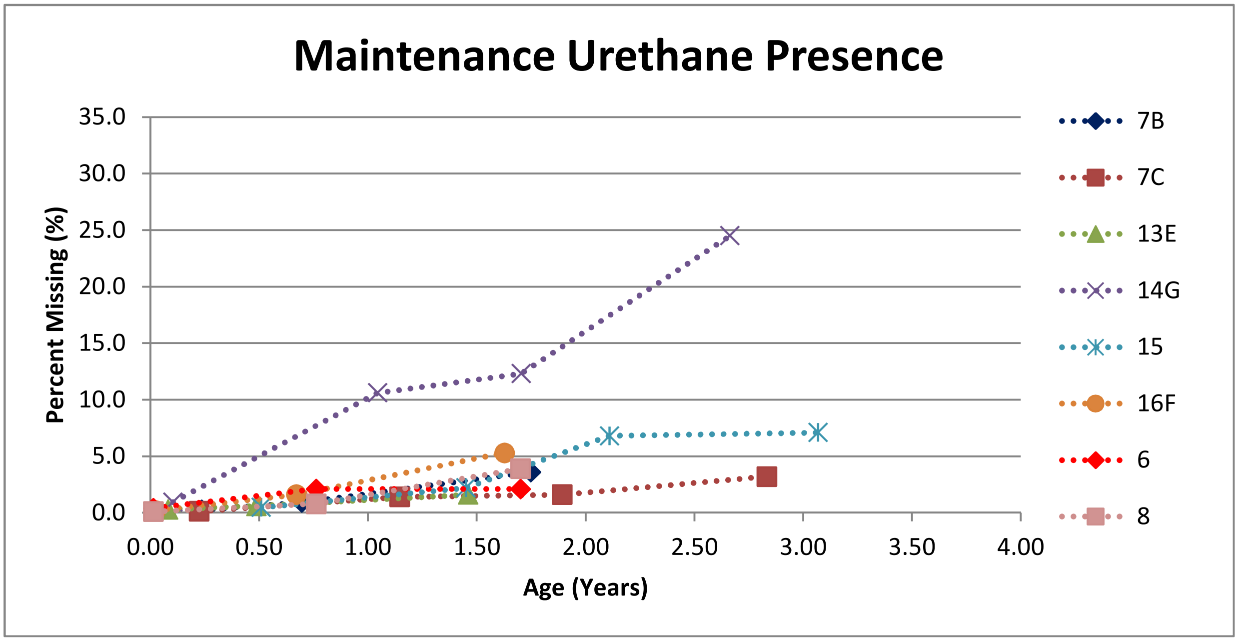


Figure 49. Maintenance urethane presence.

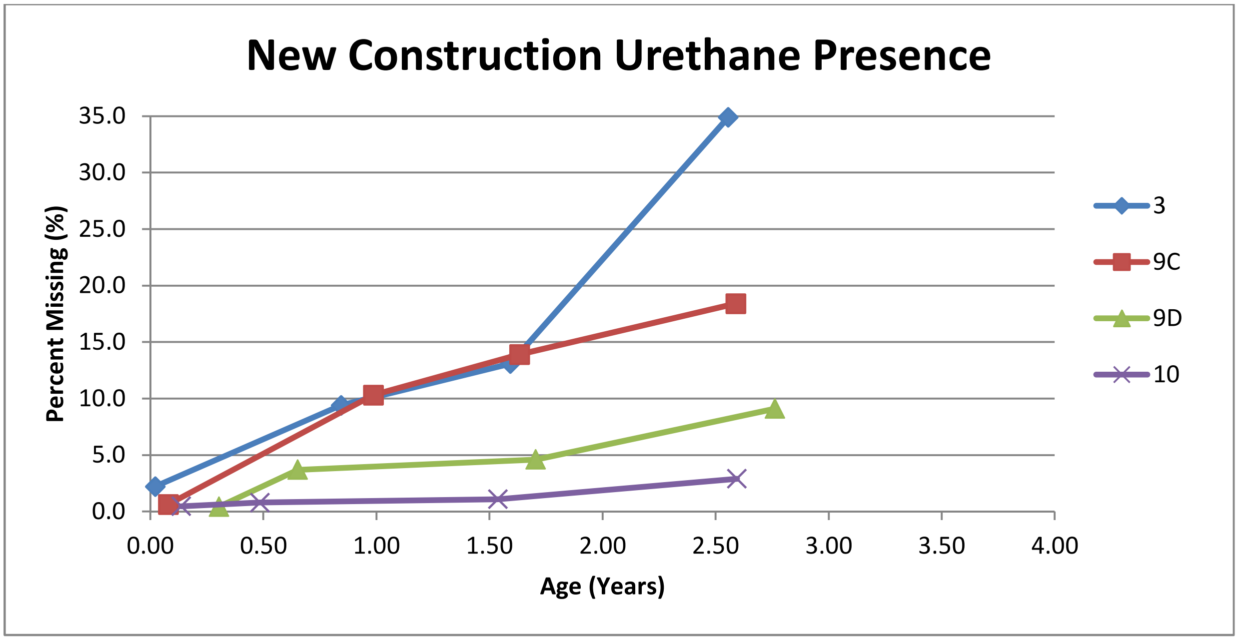


Figure 50. New construction urethane presence.

The PMI for each urethane site is graphically represented in Figure 51 and Figure 52. Two of the new construction sites fell below an index of 80.

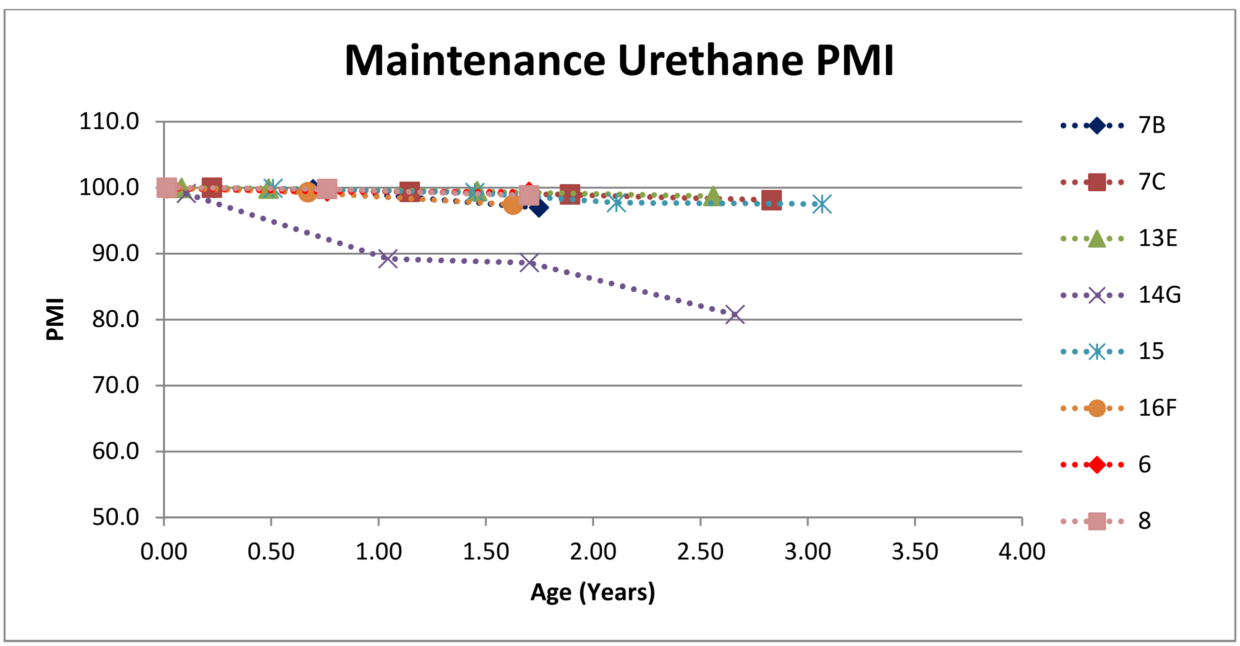


Figure 51. Maintenance urethane Pavement Marking Index.

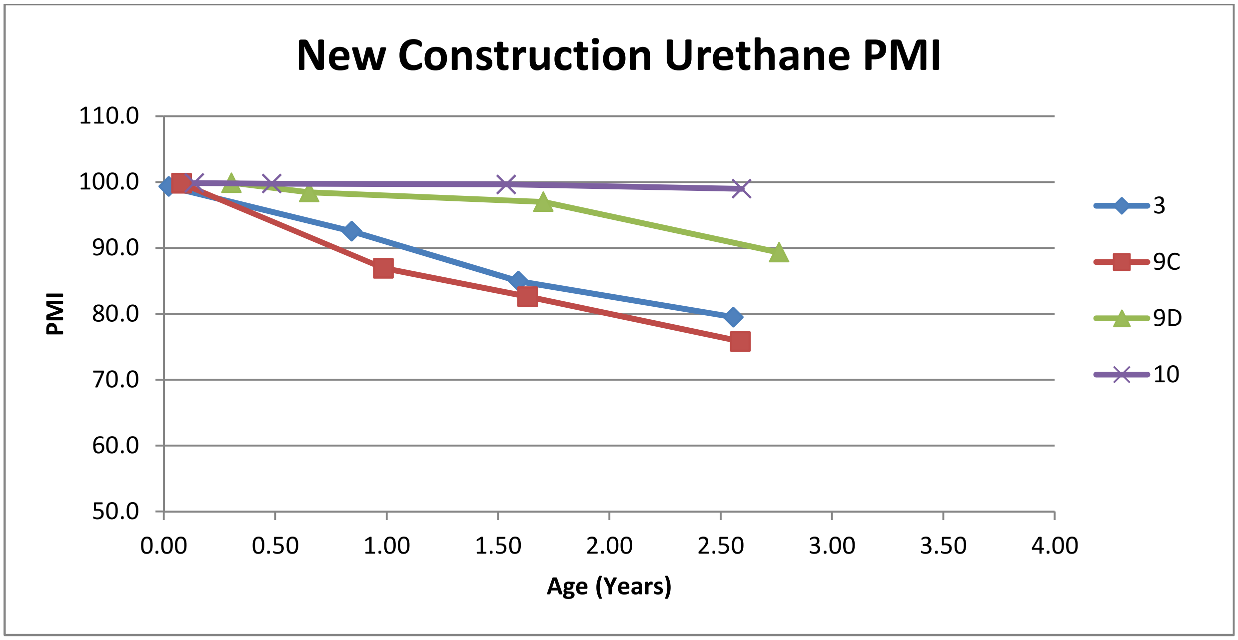


Figure 52. New construction urethane Pavement Marking Index.

2.7. RESULTS

Tape-23 was the site with the highest average retroreflectivity with an initial R_l of 926 mcd/m^2/lux at 1.21 years. Tape-23 and Tape-10B had the highest retroreflectivity values until Tape-10B's R_l value fell below Poly-3's around year 2.2. Poly-3 had a maximum measured retroreflectivity of 618 mcd/m^2/lux at 0.64 years. By the end of the study, Poly-3 had the highest retroreflectivity with a value of 500 mcd/m^2/lux around 2.7 years.

The test sites with the lowest initial retroreflectivities were Paint-37A and Thermo-37C at 197 and 191 mcd/m^2/lux, respectively. Several paint sites might have been the first to fail for retroreflectivity, but these sites were restriped before data collection could confirm this. Poly-13 had the lowest measured average retroreflectivity of 88 mcd/m^2/lux at 1.32 years, which continued to fall to 62 at 3.08 years. Poly-15 was the only other site to have a failing measured average retroreflectivity.

Paint-18A was the only site to be completely worn away after one winter. The second highest percent missing after one winter was Single-Layer Paint-17B at 17.8%. The non-paint site that showed the highest percent missing after one winter was a new construction thermoplastic, Thermo-3, at 14.6% missing at an age of 0.88 years. Of the non-tape materials, Thermo-33B had the best presence after one winter with 0.4% missing at 0.77 years. After three winters, Urethane-3 was the site with the worst presence at 34.9% missing. Poly-3 was the non-tape site with the best presence with 1.6% missing at 2.73 years.

Based on collected data, the overall best performing markings were Poly-3, Tape-23, and Tape-10B, and out of the three top markings, Poly-3, a surface-applied marking in Zone 1, exhibited the lowest rate of retroreflectivity deterioration, losing only 19% of its highest initial R_l value. Based on the definitions of retroreflectivity, presence, and PMI failure described in Section 1, only Paint-18A, Poly-13, and Poly-15 showed a confirmed failure. Fifteen paint and eight non-paint research sites were restriped before failure was concluded by data.

Observations of new construction paint sites with single and double layer of material resulted in interesting comparisons. Table 18 lists the percentage loss of both retroreflectivity and presence after one winter for the maintenance paint sites. Table 19 lists the same data for the new construction paint sites with columns for both single and double-layer paint. The double-layer new construction sites had the lowest percentage loss for both retroreflectivity and presence.

Figure 53 summarizes the collective range of retroreflectivity values for all test sites for each year of the study, and Figure 54 summarizes the collective range of presence values for all test sites for each year of the study. Overall deterioration rates can be interpreted from these graphs. Poly-3, Tape-23, and Tape-10B were in the >400 mcd/m^2/lux category in 2013, and tapes constituted the 0-1% missing category in 2013.

Table 18. Maintenance Paint Percentage Loss

Site #	ADT	Zone #	Pavement Type	Application	% Retroreflectivity Loss	Presence Loss
					2011	2011
13	2200-3650	2	HMA	Surface	36.1	6.5
21B	4650-5600	3	HMA	Surface	50.5	1.0
37A	8,300	2	HMA	Surface	35.0	15.4
37B	16,200	2	HMA	Surface	40.8	5.6
Average					40.6	7.1

Table 19. New Construction Paint Percentage Loss

Site #	ADT	Zone #	Pavement Type	Application	% Retroreflectivity Loss		Presence Loss	
					Single Layer	Double Layer	Single Layer	Double Layer
1A	2,700	1	HMA	Surface	13.2	13.0	5.0	1.6
9C	4,200	2	HMA	Surface	25.8	23.4	6.2	0.7
9F	25	2	HMA	Surface	34.2	2.1	5.6	1.1
12	1,100	2	Micro-Surface	Surface	12.9	0.4	15.2	0.5
17B	4,200	3	HMA	Surface	14.2	-2.5	16.9	0.0
Average					20.1	7.3	9.7	0.8

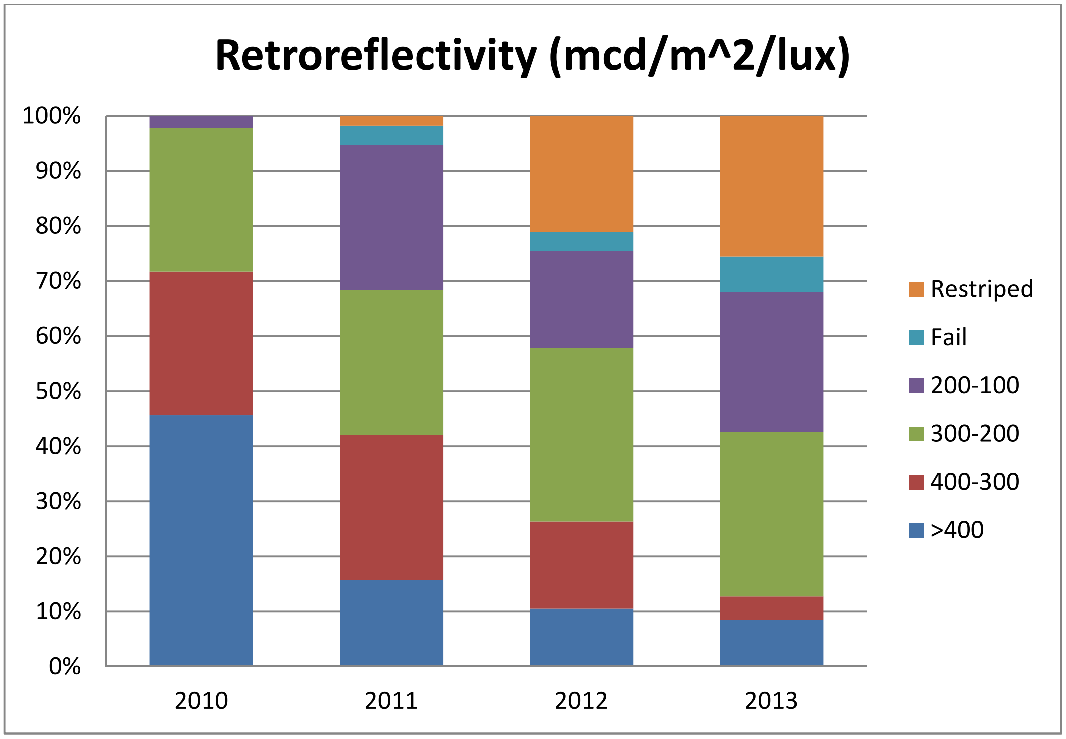


Figure 53. Summary of collective retroreflectivity ranges for each year of the study.

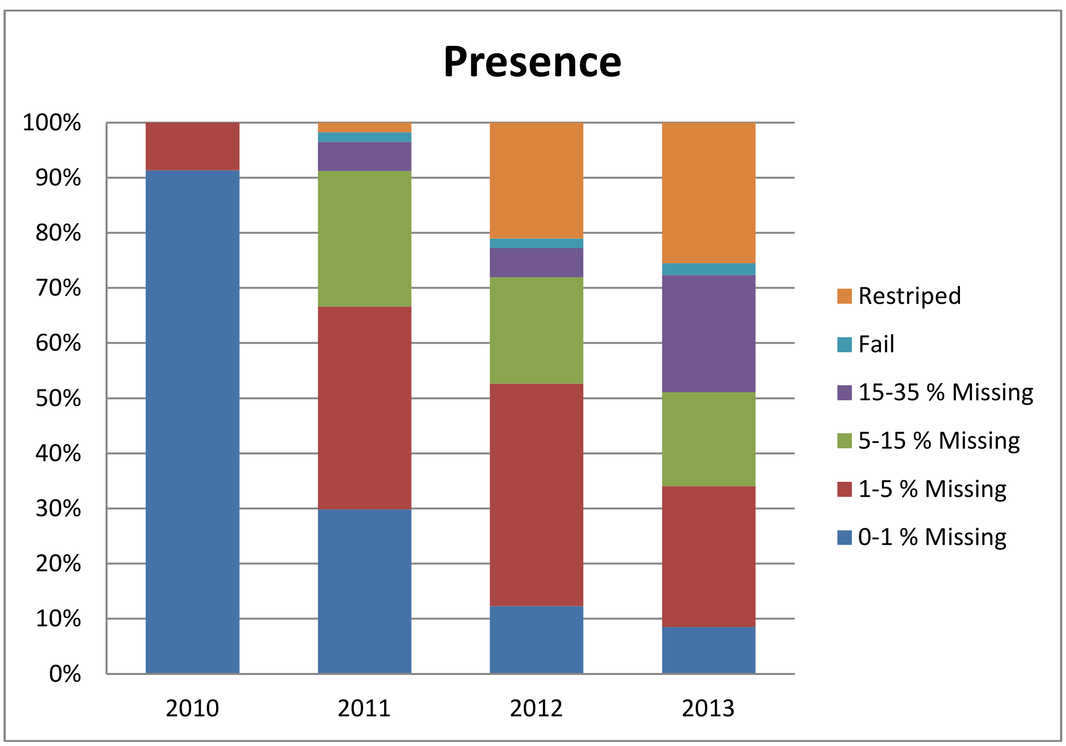


Figure 54. Summary of collective presence ranges for each year of the study.

CHAPTER 3 SERVICE LIFE PROJECTIONS

To select the optimum markings for a given location, it is important to know the length of service life for each of the markings. For this study, the end of service life (ESL) is equivalent to the age at which a marking's performance reaches the PMI failure threshold. The ESL was confirmed for three research sites between 2010 and 2013, while a projected ESL is required for the remaining sites to be considered for marking selection. Measured performance, Illinois Tollway marking performance, and site criteria were used to project the retroreflectivity and presence for each site. The PMI was then calculated from those projections to create a projected PMI.

The mild winter between 2011 and 2012 created an obstacle to creating dependable projections for all marking types.. The exceptional weather may have caused the markings to deteriorate slower than typical weather. The lack of local data that can be used for comparisons represented yet another challenge. This is especially significant in presence projections because the use of presence as a metric for marking performance was very limited. Appendix C includes a table that contains the age of each marking site at failure, measured or projected, for each metric (retroreflectivity and presence) and for the PMI.

3.1. PAINT

Figure 55, Figure 56, and Figure 57 display the retroreflectivity projections for paint sites. The lines in each graph represent the projected performance while measured data points are marked with symbols. Paint projections are primarily based on data points and the fact that it is not considered a "durable" material. Paint is not typically expected to last through two winters in Illinois. Concurrently, the maintenance paint on HMA had a projected service life between 1.2 and 1.5 years.

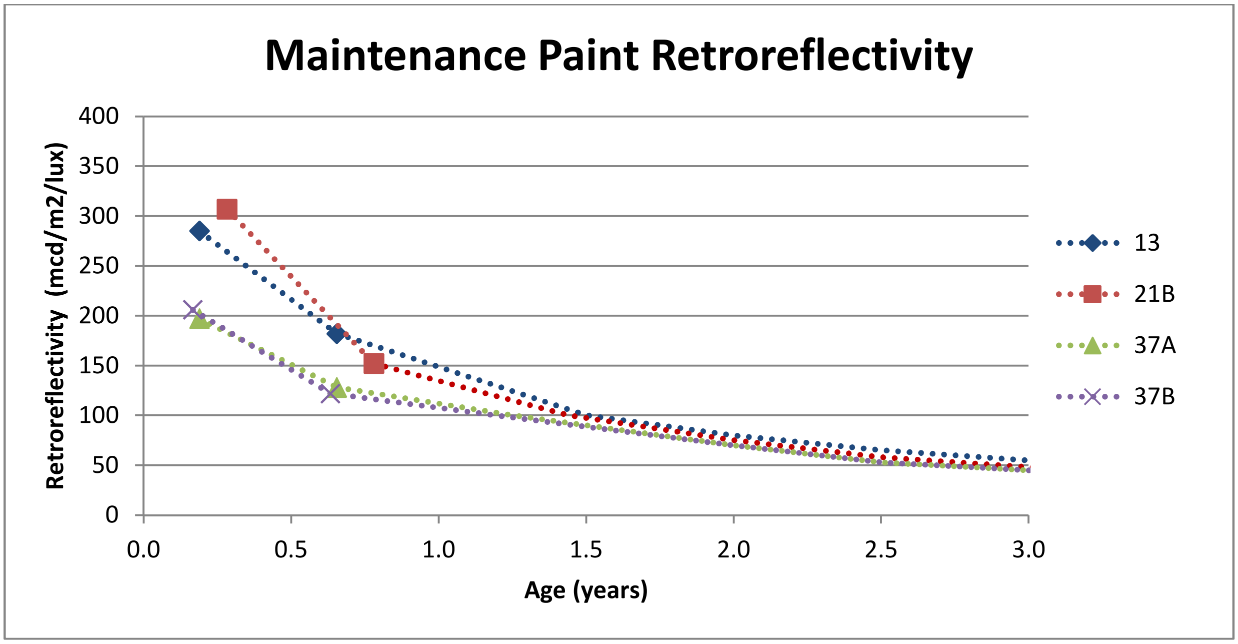


Figure 55. Projected maintenance paint retroreflectivity.

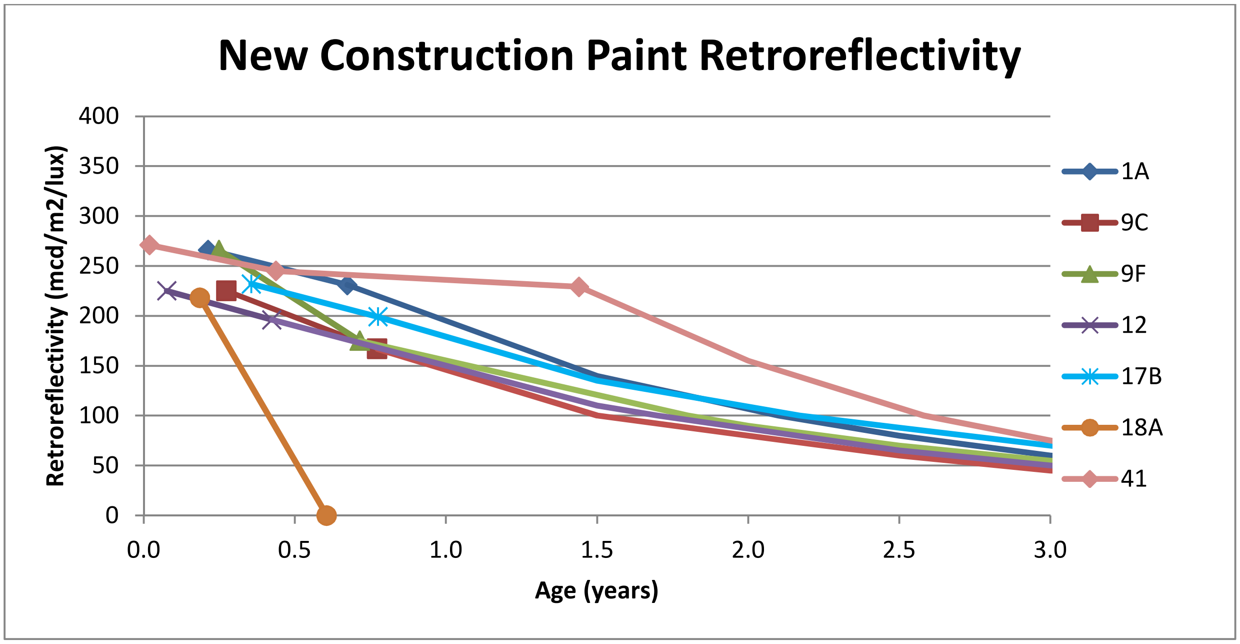


Figure 56. Projected single-layer new construction paint retroreflectivity.

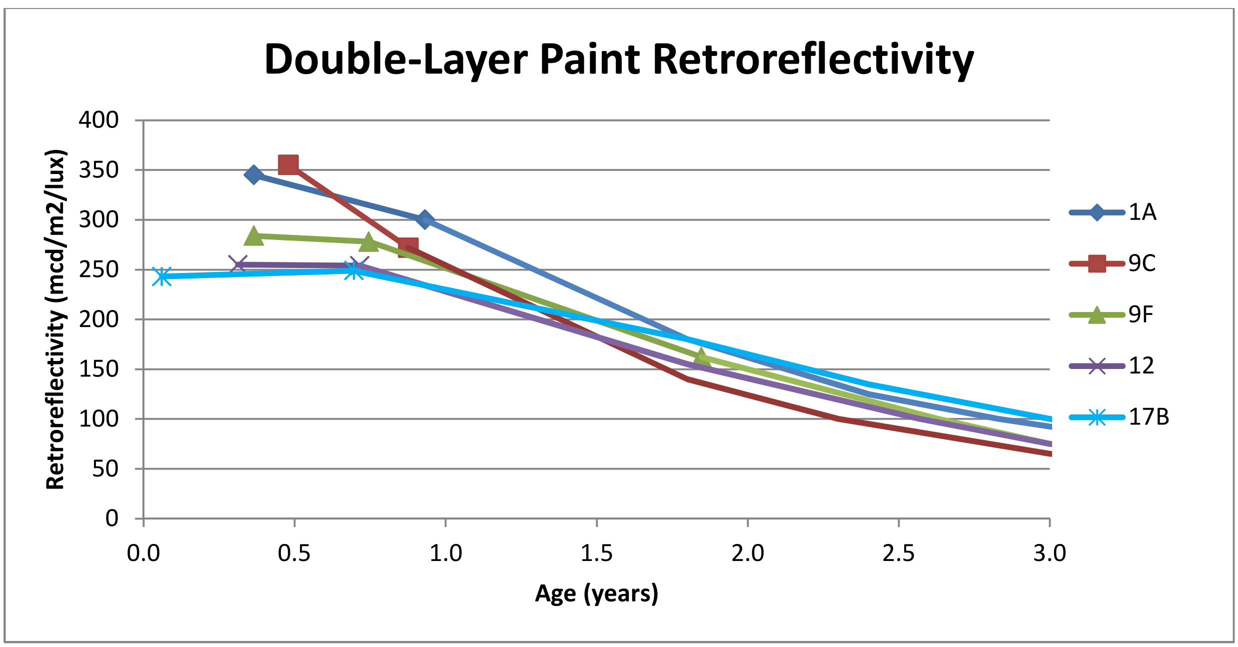


Figure 57. Projected double-layer new construction paint retroreflectivity.

Paint-18A did not have enough material to support the collection of retroreflectivity data; its failure is attributed to a presence failure rather than a retroreflectivity failure. New construction paints on HMA are projected to fail between 1.5 and 2.6 years. The values of double-layer paint on new pavement range from 2.3 to 3.0 years.

The paint projections for presence are shown in Figure 58, Figure 59, and Figure 60. Paint presence tends to reach complete failure (percentage missing = 55) after retroreflectivity.

The maintenance paint sites are projected to fail between 3.0 and 4.2 years for presence compared with the 1.2 to 1.6 years for retroreflectivity. New construction sites had similar projection values of 2.9 to 3.8 years. Failure of Paint-18A was observed at 0.6 years or the equivalent of one winter. The failure values for double-layer new construction sites ranged between 4.1 and 4.9 years, however, these values might be higher because of the mild winter which caused less deterioration in the measured data.

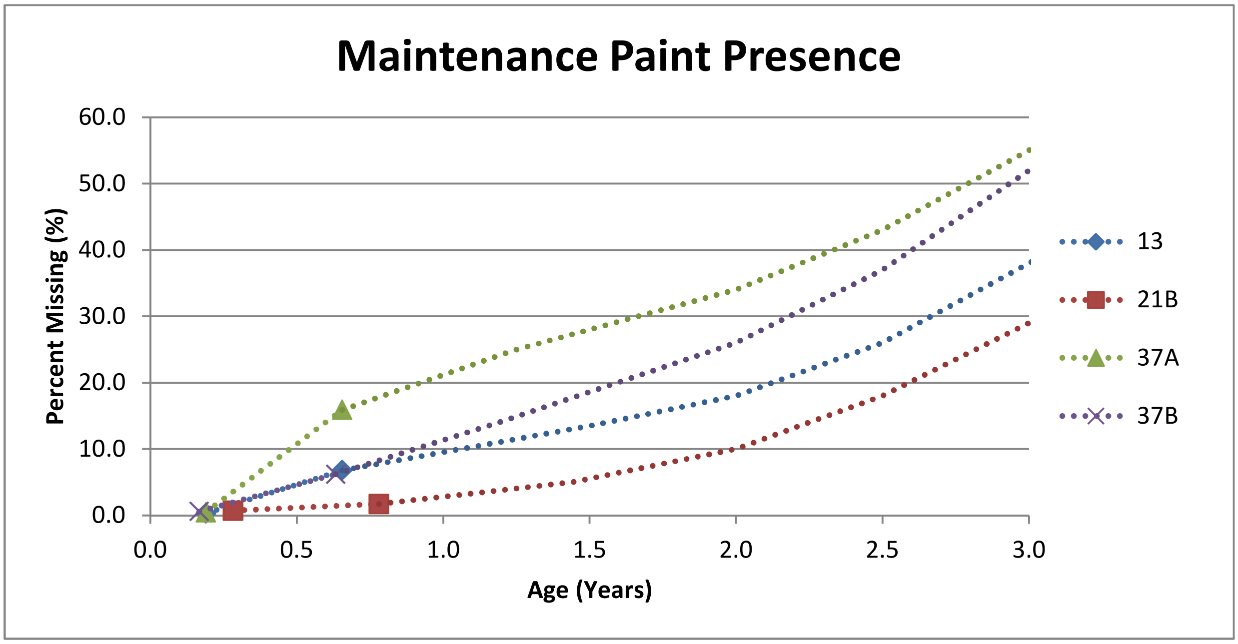


Figure 58. Projected maintenance paint presence.

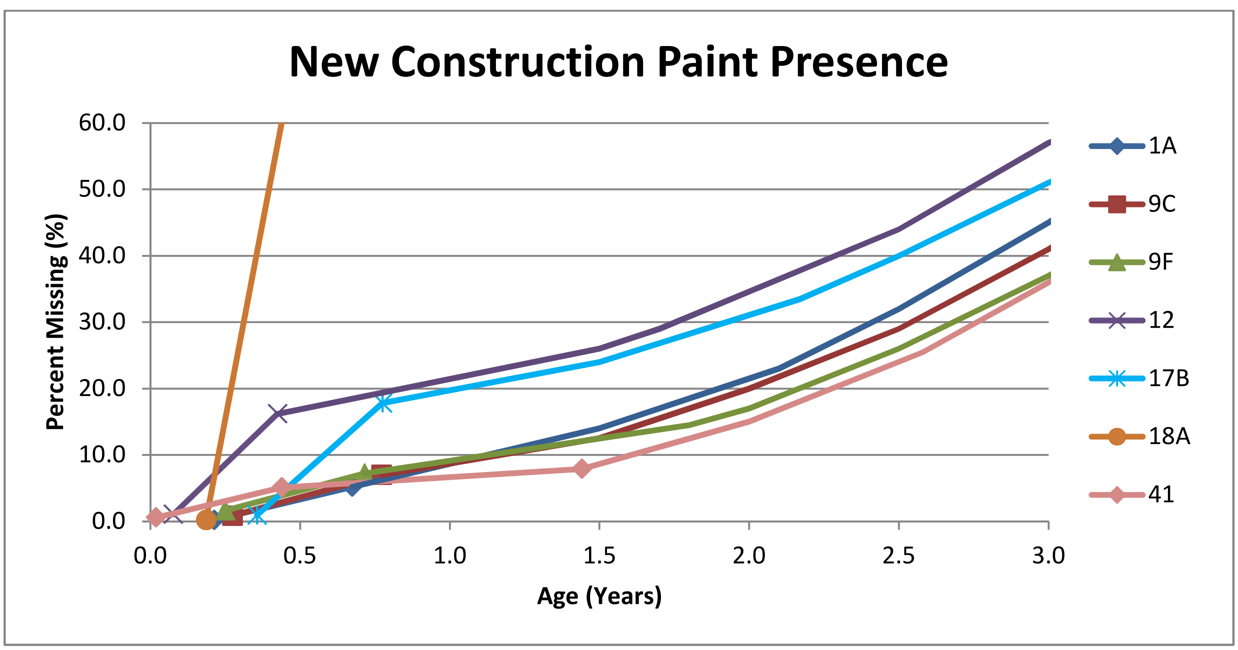


Figure 59. Projected single-layer new construction paint presence.

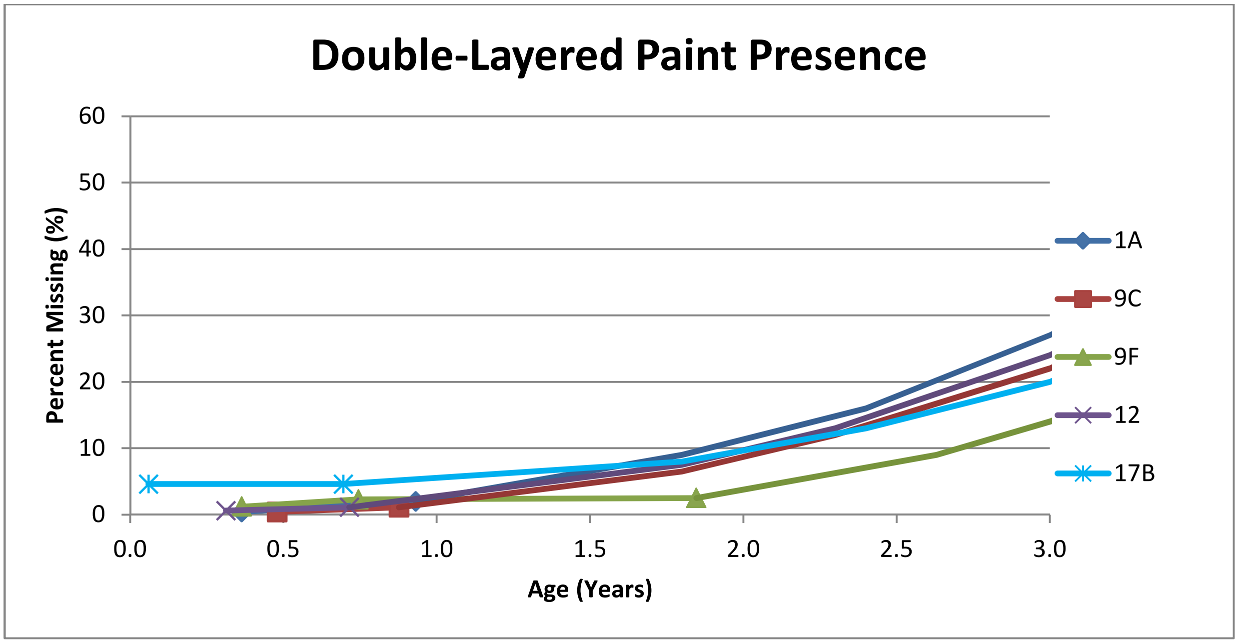


Figure 60. Projected double-layer new construction paint presence.

The calculated PMI projections are shown in Figure 61, Figure 62, and Figure 63. The PMI failure, or ESL, for maintenance paint sites ranged from 1.0 to 1.4 years, slightly lower than the projected retroreflectivity failure range. This projection indicates that paint on older pavement needs to be restriped every year.

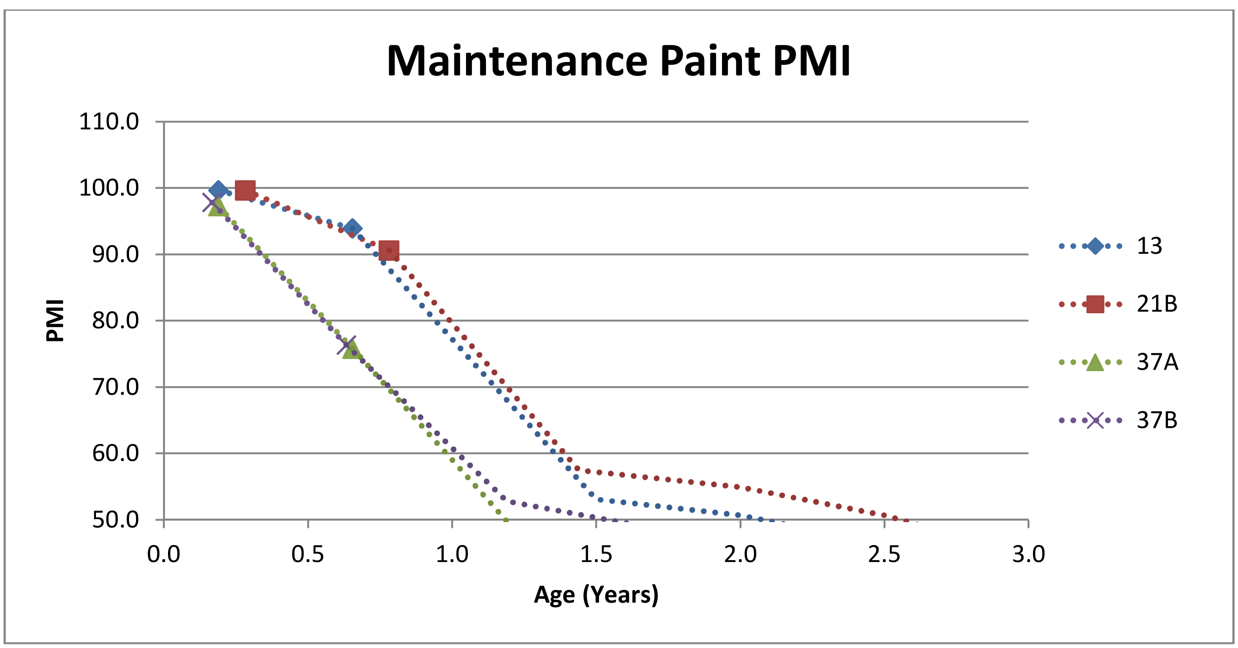


Figure 61. Projected maintenance paint Pavement Marking Index.

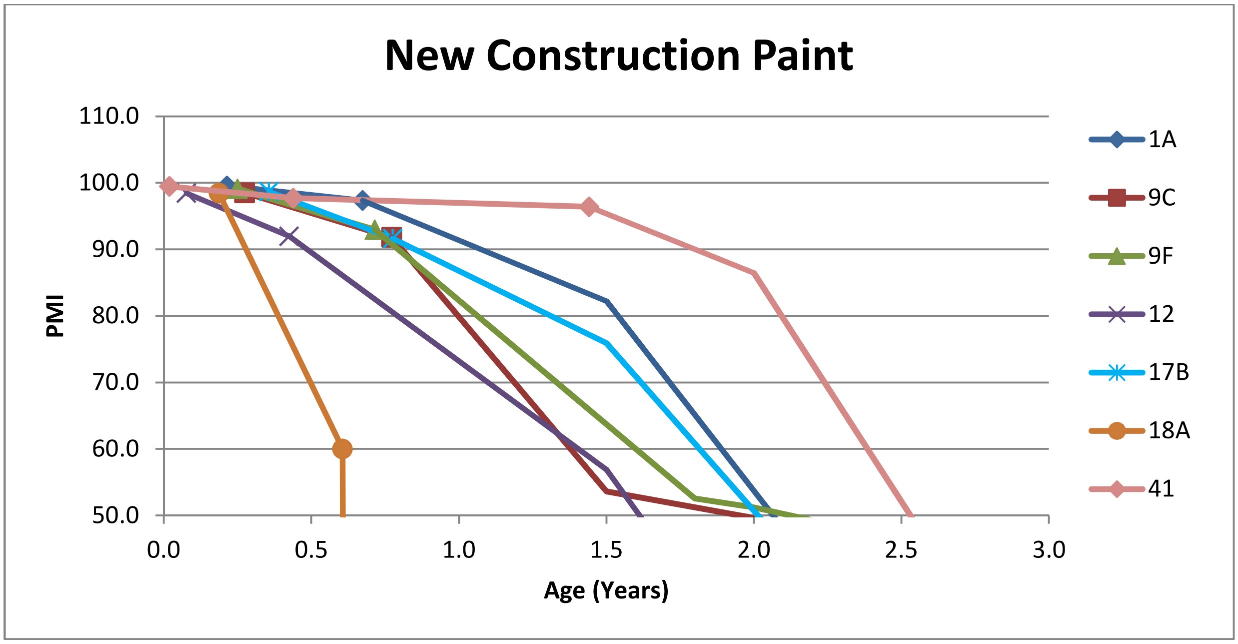


Figure 62. Projected new construction paint Pavement Marking Index.

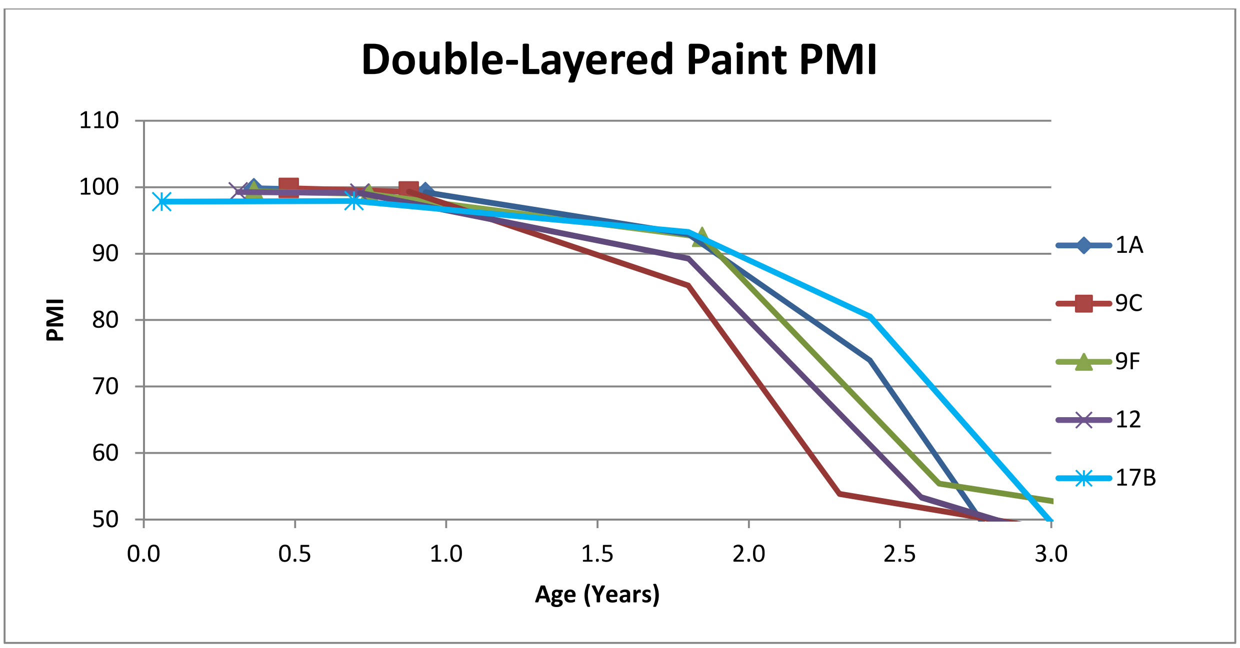


Figure 63. Projected double-layer new construction paint Pavement Marking Index.

The values of single-layer new construction ESL ranged from 1.4 to 2.4 years. These values are often a bit lower than the age at retroreflectivity failure because these sites experience a lot of presence deterioration after one winter. The double-layer ESL values were between 2.2 and 2.8 years. Based on these projections, some single-layer and all double-layer paint sites on new HMA pavement should survive more than one winter and should be evaluated more closely before being automatically restriped every year.

3.2. THERMOPLASTIC

The projected retroreflectivity of maintenance and new construction thermoplastic is plotted in Figure 64 and Figure 65, respectively. Thermoplastic projections are based on collected data and literature reviews as there are no thermoplastic research sites on the Illinois Tollway. The retroreflectivity projections suggest that new construction site Thermo-17B will last the longest, 6.5 years. Thermo-17C and Thermo-41 are also expected to last near 6 years. These sites, which were all located in Zone 3, sustained high measured retroreflectivity values in the 2013 data collection. Maintenance sites Thermo-37A and 37C are expected to fail the earliest at 3.6 and 3.2 years, respectively. These lower values are due to the different type of thermoplastic used.

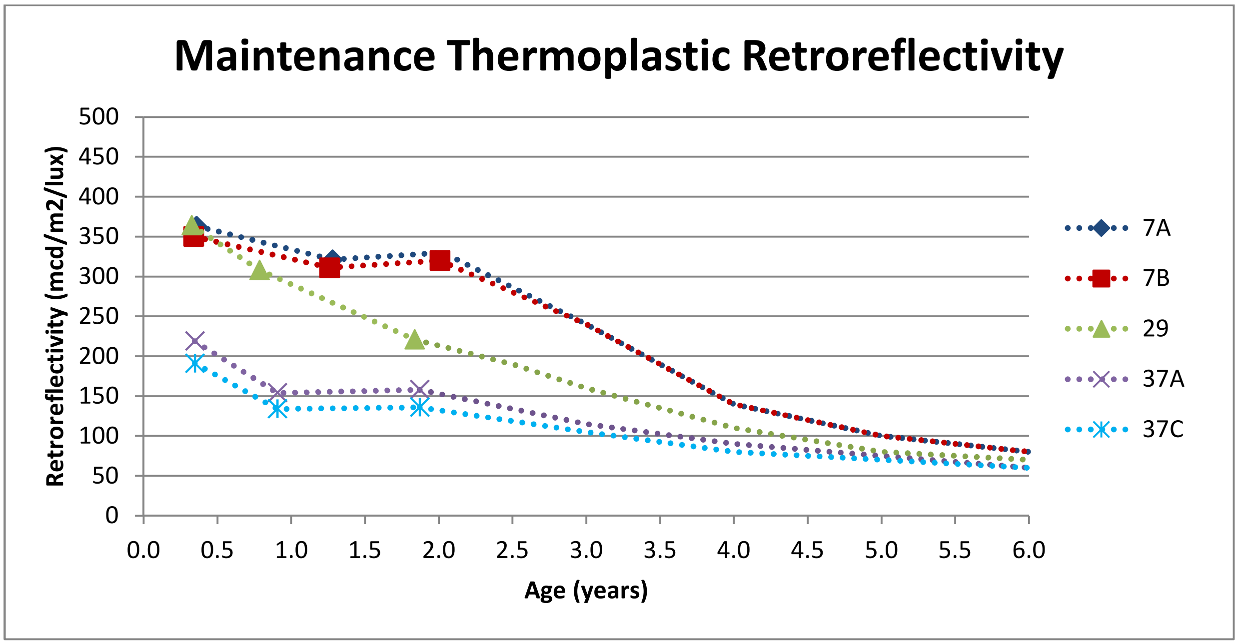


Figure 64. Projected maintenance thermoplastic retroreflectivity.

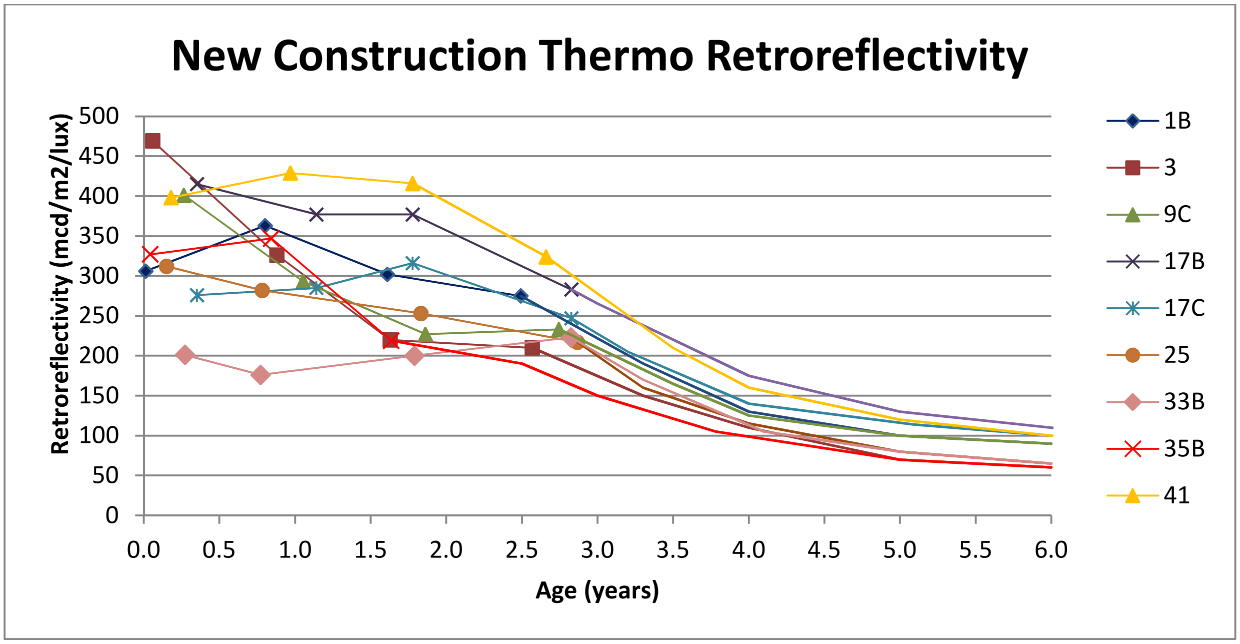


Figure 65. Projected new Construction thermoplastic retroreflectivity.

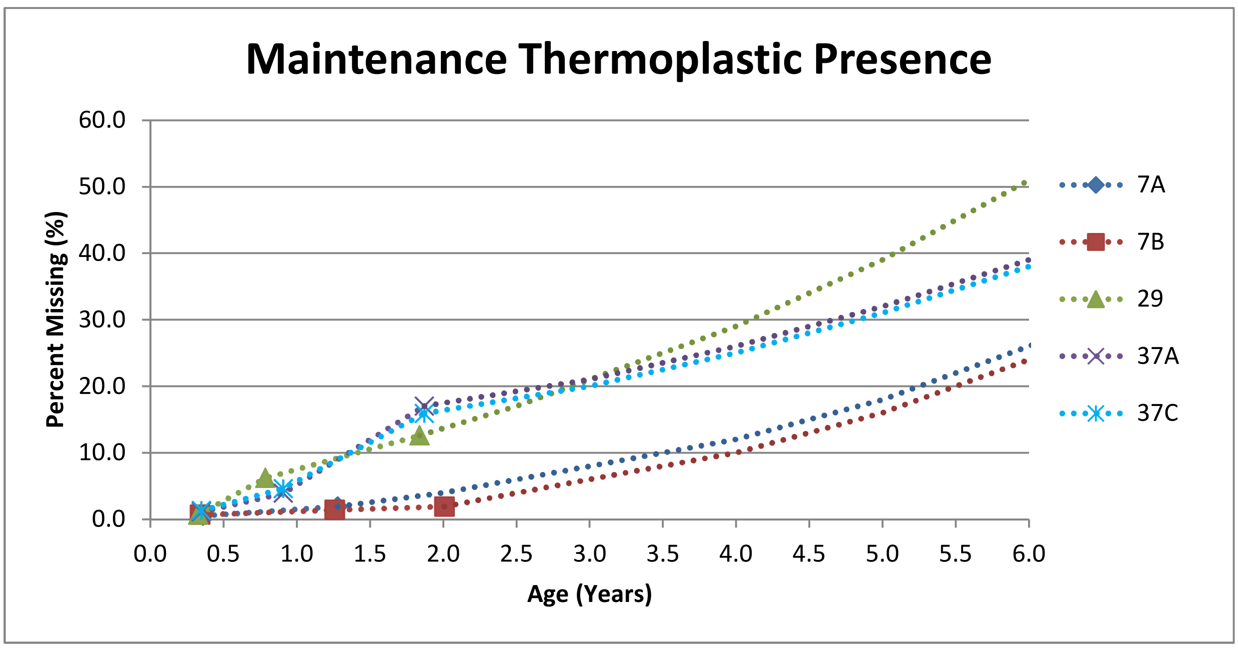


Figure 66. Projected maintenance thermoplastic presence.

Thermoplastic projections for presence are shown in Figure 66 and Figure 67. Because of their recessed application Thermo-37A and 37C should retain a passable presence for the longest time, however, pavement deterioration started to cause more loss of marking than expected. Thermo-9C and 17B might be very durable because of their southern locations and low ADT. Thermo-3 and 17C had the fastest deterioration. These two sites are located in opposite zones and have similar ADTs, but they are both important county routes leading into urban areas so they may get plowed more often than other rural routes.

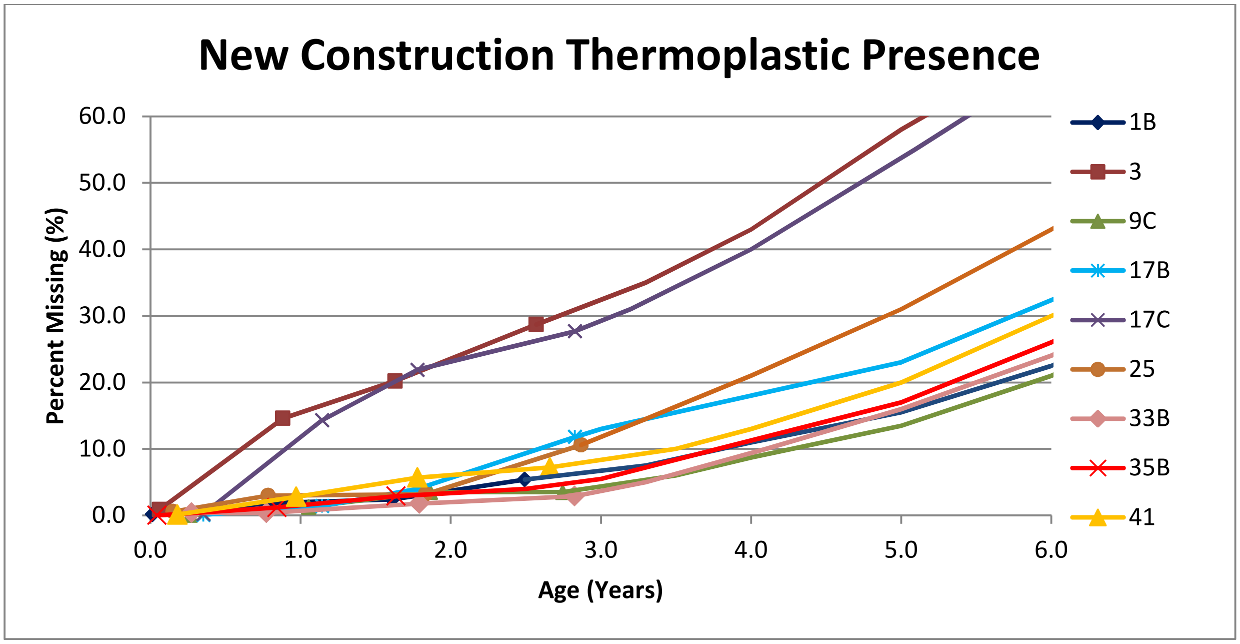


Figure 67. Projected new construction thermoplastic presence.

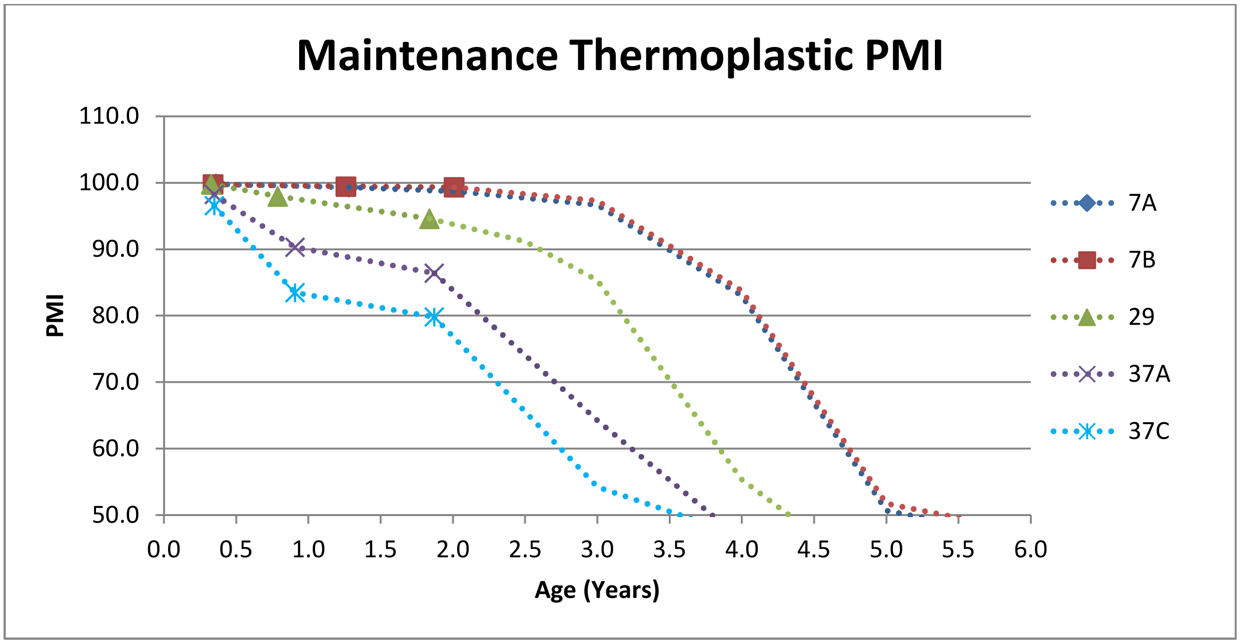


Figure 68. Projected maintenance thermoplastic Pavement Marking Index.

Thermoplastic projections for PMI are shown in Figure 68 and Figure 69. Presence plays a significant role in thermoplastic ESL because the thicker marking is exposed to more punishment by plows. For example, maintenance site Thermo-3 had a projected retroreflectivity life of 4.3 years but the ESL was 3.6 years because the large amount of material missing rendered the marking ineffective.

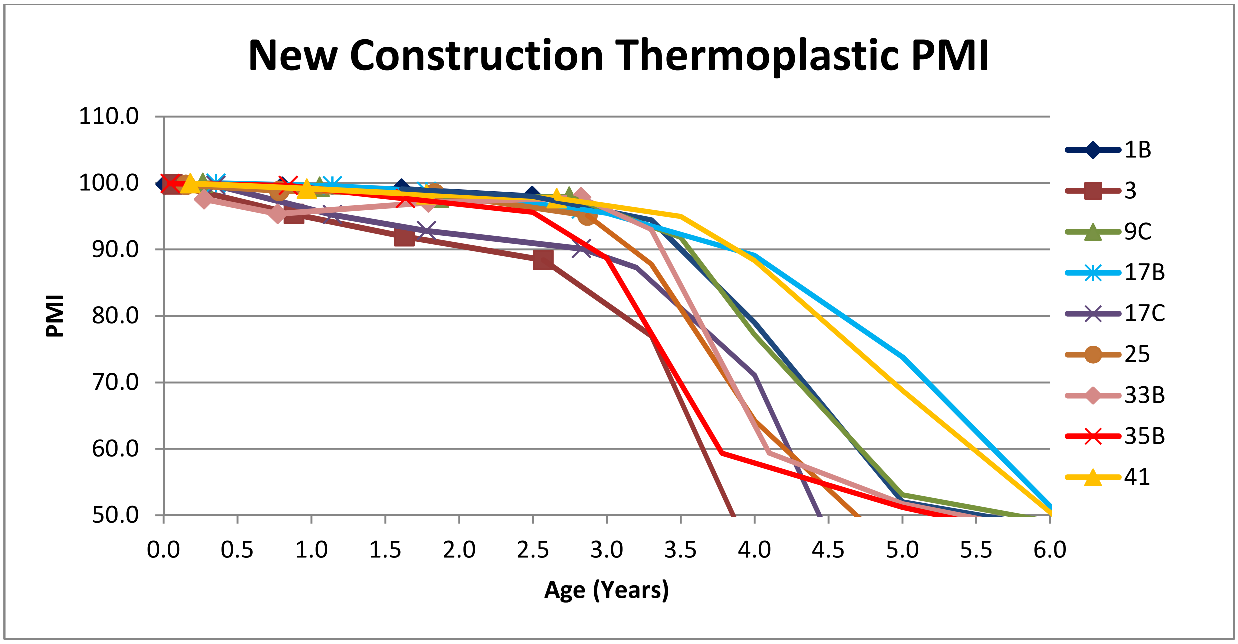


Figure 69. Projected new construction thermoplastic Pavement Marking Index.

New construction site Thermo-17C was one of the few sites for which the presence reached failure before the retroreflectivity. Similar to Thermo-3, the ESL of Thermo-17C was lower than both projected retroreflectivity and presence age at failure. Thermo-3 was the thermoplastic site with the shortest effective service life at 3.6 years. The values of the remaining sites varied from 3.8 to 5.6 years. Thermo-17B is projected to be the best performing thermoplastic. Some of these projections are higher than the industry's expected service life of 3-4 years for thermoplastic because presence is more difficult to extrapolate with changing weather and plowing patterns.

3.3. TAPE

Tape projections are modeled after Illinois Tollway tape data. The projected retroreflectivity over time is shown in Figure 70. The retroreflectivity failure for tape sites ranged from 3.5 to 6.8 years. Tape-23 is projected to last the longest because it is recessed in the southern zone. Tape-1 had a very low average retroreflectivity in 2013 data collection and is expected to fall below the failure threshold after the next winter.

The presence projections, presented in Figure 71, show little deterioration even for the surface-applied Tape-1. A recessed tape will retain a good presence as long as the bond with the pavement surface remains intact. Figure 72 shows the projected PMI for all tape sites. The ESLs are very close to the predicted age of retroreflectivity failure.

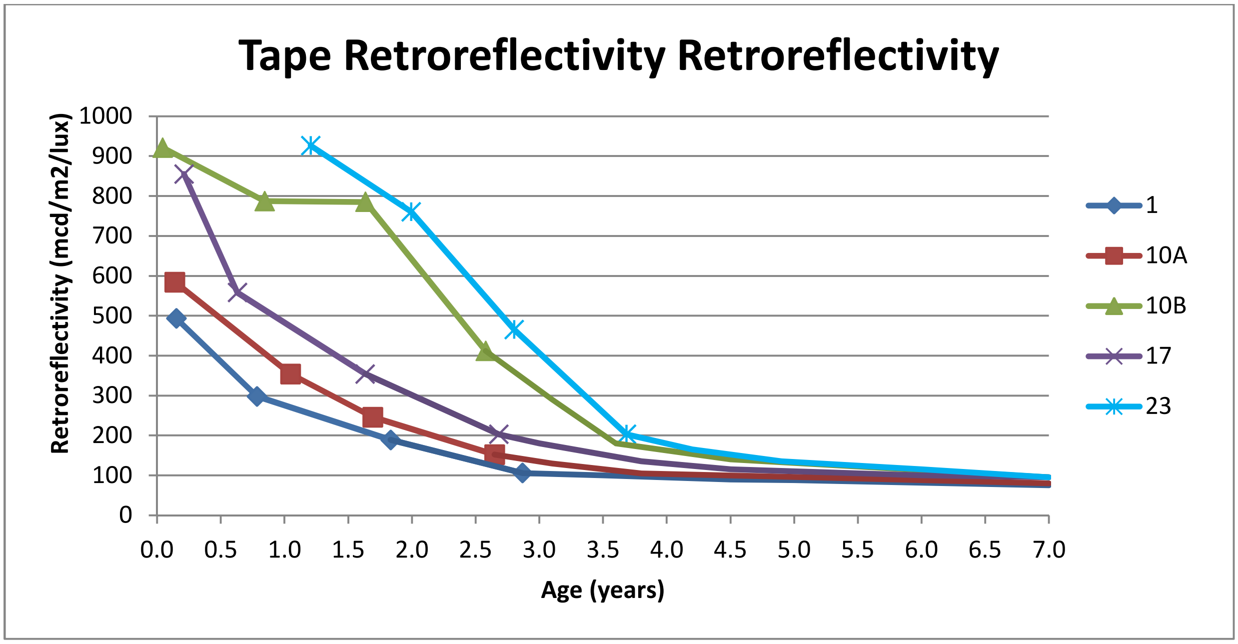


Figure 70. Projected tape retroreflectivity.

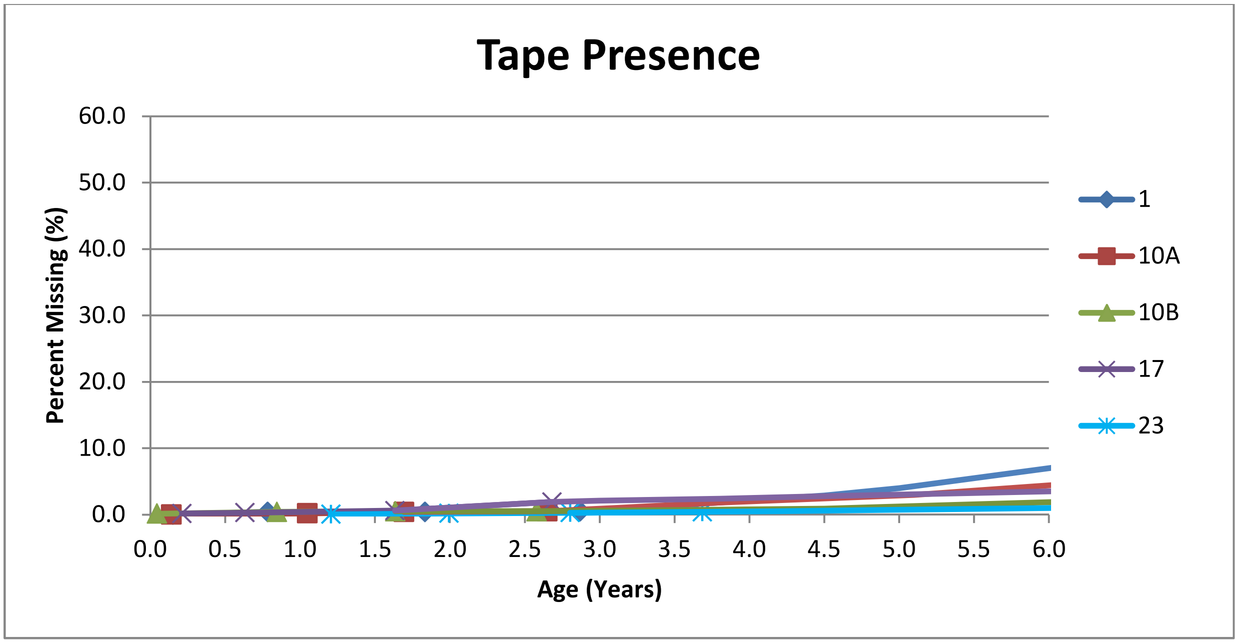


Figure 71. Projected tape presence.

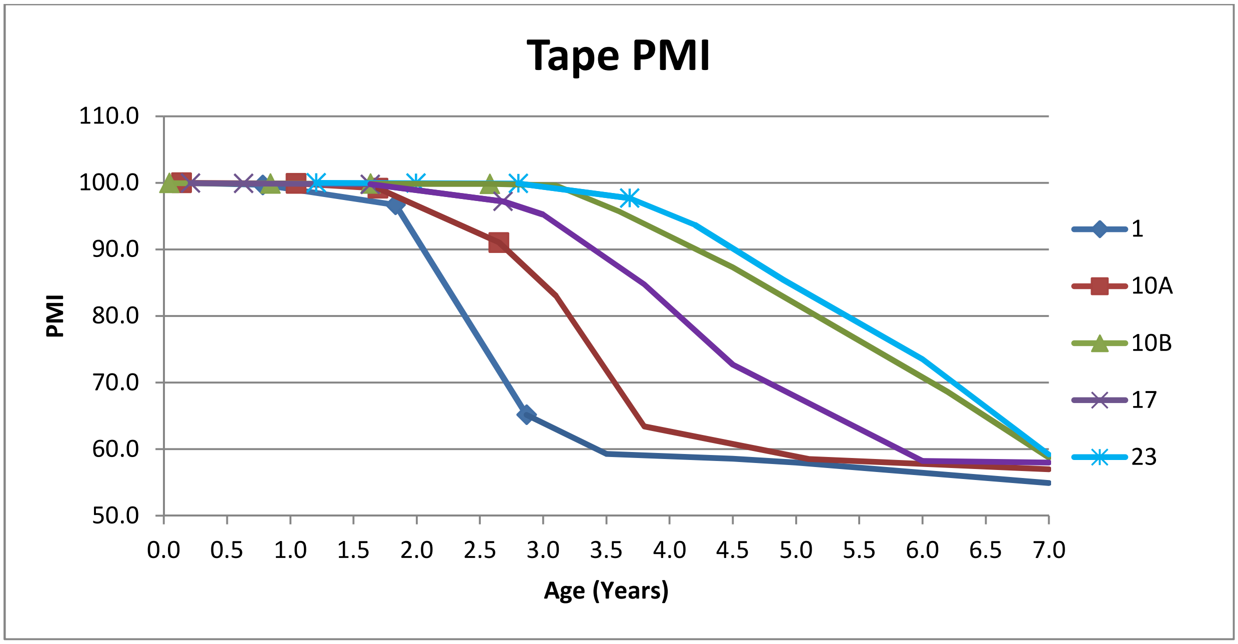


Figure 72. Projected tape Pavement Marking Index.

3.4. EPOXY

Figure 73 shows the epoxy projected retroreflectivity over time. These projections are derived from the Illinois Tollway surface-applied epoxy data. The projected age at retroreflectivity failure ranged from 3.9 to 4.3 years. This range is close to the expected life of 3 to 4 years for epoxy. Figure 74 shows that the presence of Epoxy-9B is already over 20% missing. This makes an impact on PMI which is projected in Figure 75. The Epoxy-9B 3.9 year ESL from retroreflectivity dropped to 3.5 years when presence was taken into account using the PMI.

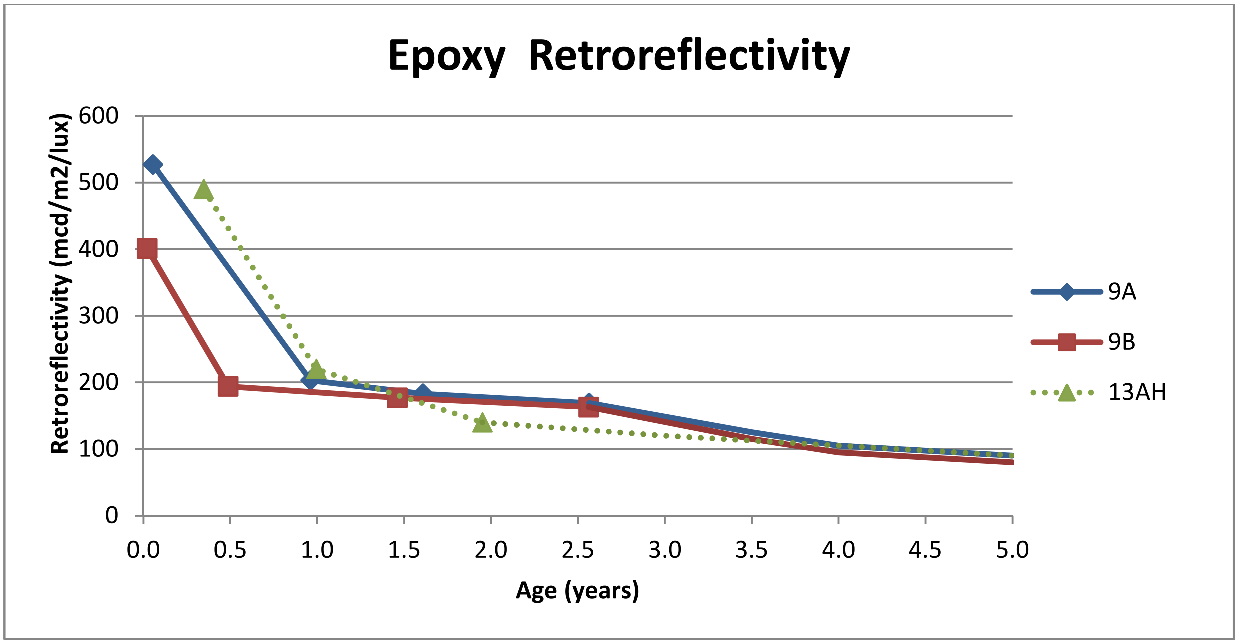


Figure 73. Projected epoxy retroreflectivity.

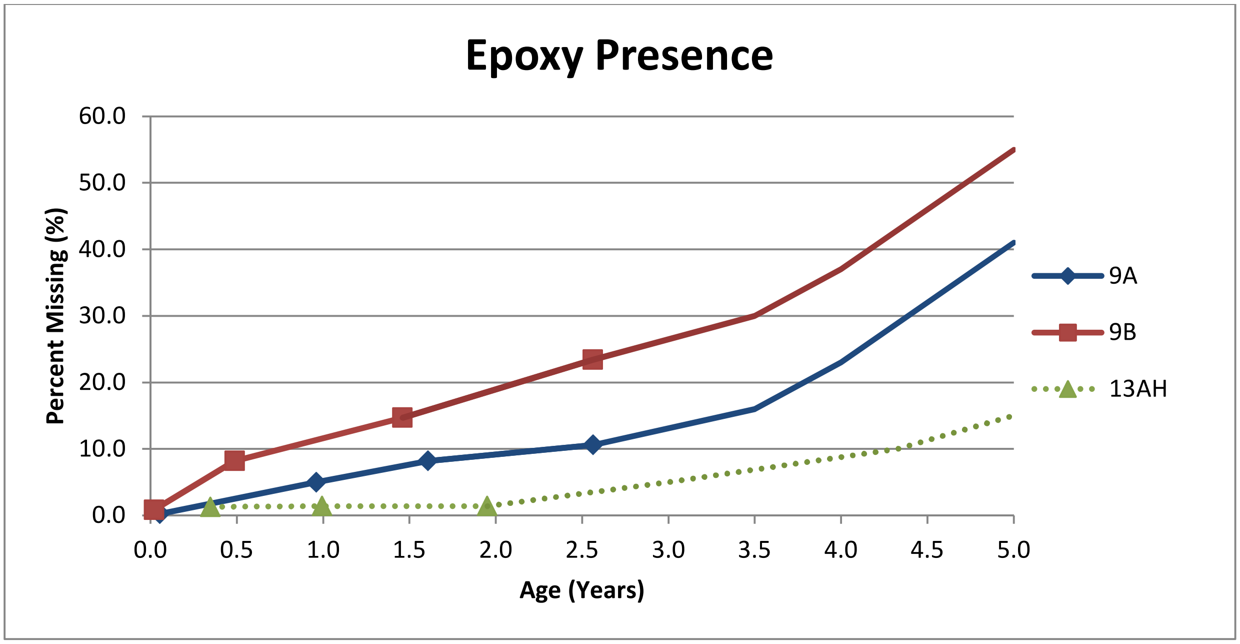


Figure 74. Projected epoxy presence.

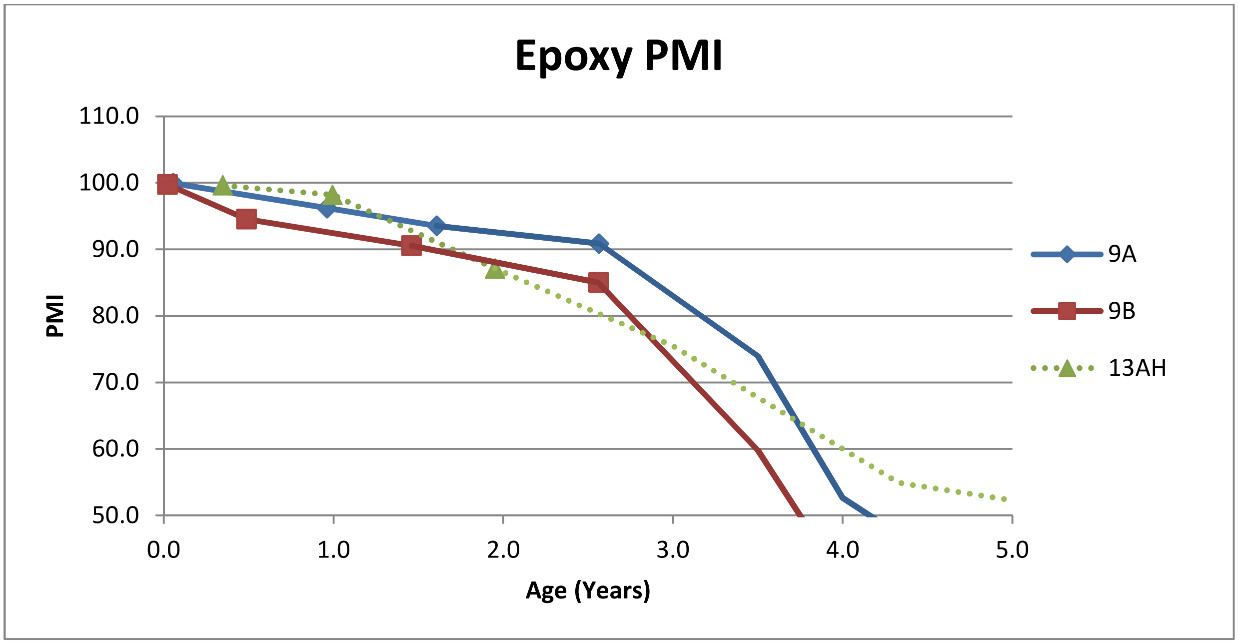


Figure 75. Projected epoxy Pavement Marking Index.

Figure 75 depicts the graph of projected PMI which shows that the end of service life for the epoxy sites ranged from 3.5 to 4.0 years. The projection of Epoxy-13AH data had less support than 9A and 9B because there were three data points only and this was the only maintenance epoxy site included in the study.

3.5. POLYUREA

The failure of two polyurea sites, Poly-13 and Poly-15, was observed during data collection. Poly-13 was the only site where the measured retroreflectivity failed after one winter. Projections for the other sites were based on Illinois Tollway data. Figure 76 shows the retroreflectivity data and projections of all polyurea sites. The maintenance sites had significantly lower values ranging from 1.3 to 4.8 years. New construction polyurea sites had high retroreflectivity measurements despite being surface-applied. These sites could retain an adequate retroreflectivity up to 7.0 years.

The projections for polyurea presence, graphed in Figure 77, are in some cases specific to the conditions observed at the test sites. For example, the extremely deteriorated HMA pavement at the Poly-6 test site was patched and restriped before 2012 data collection. However, 2011 data did not reflect that the Poly-6 presence was deteriorated. The projection was designed as if the test section was not restriped and the deterioration was allowed to continue. However, this projection may not apply to other maintenance polyurea sites having similar criteria. In addition, Poly-19D's projected presence was high because of improper installation. Overall, the projected age at presence failure ranged between 5.2 and 9.3 years for all polyurea sites.

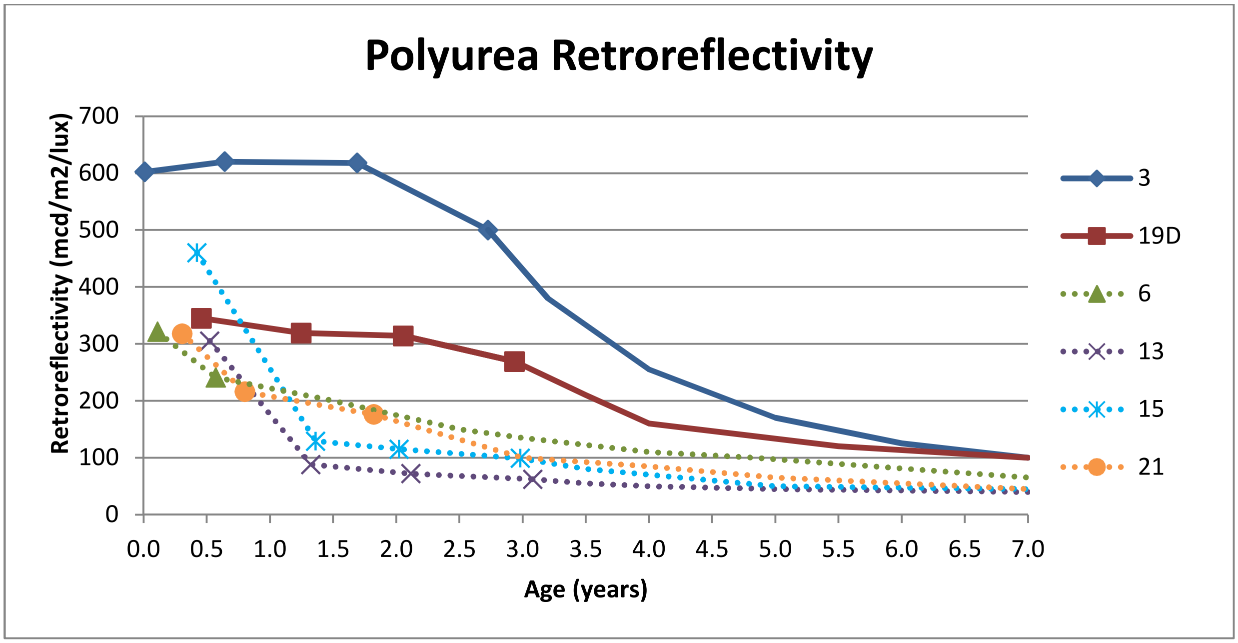


Figure 76. Projected polyurea retroreflectivity.
Note: New construction sites are solid lines. Maintenance sites are dotted lines.

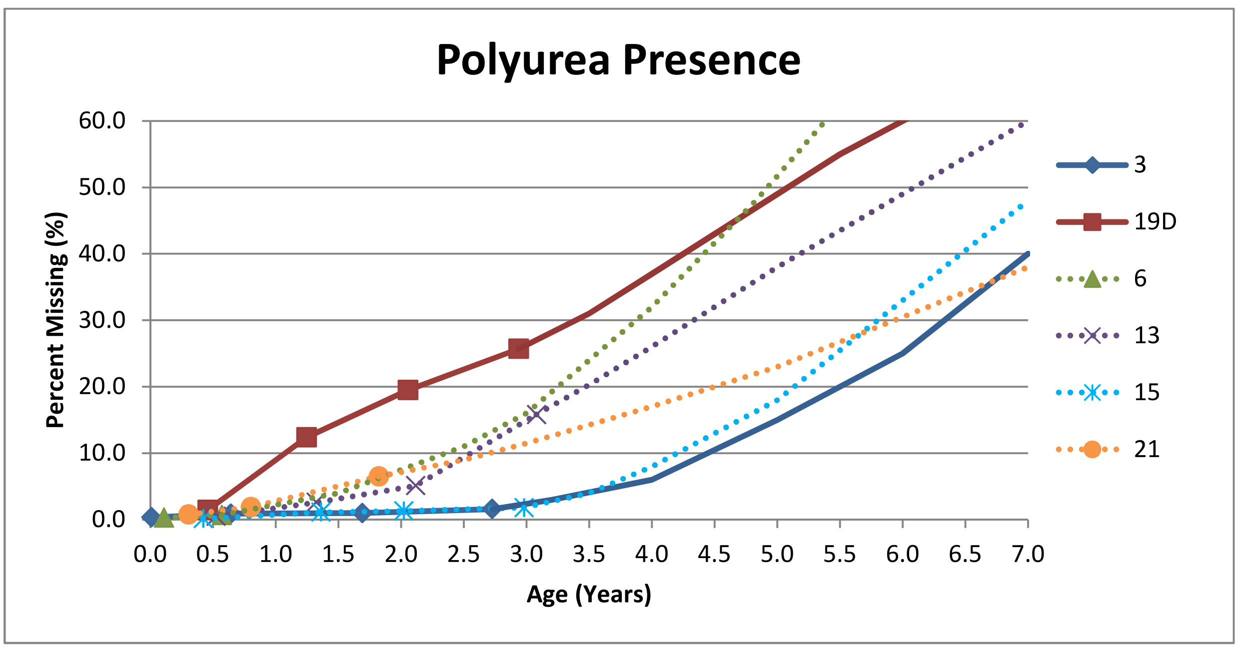


Figure 77. Projected polyurea presence.
Note: New construction sites are solid lines. Maintenance sites are dotted lines.

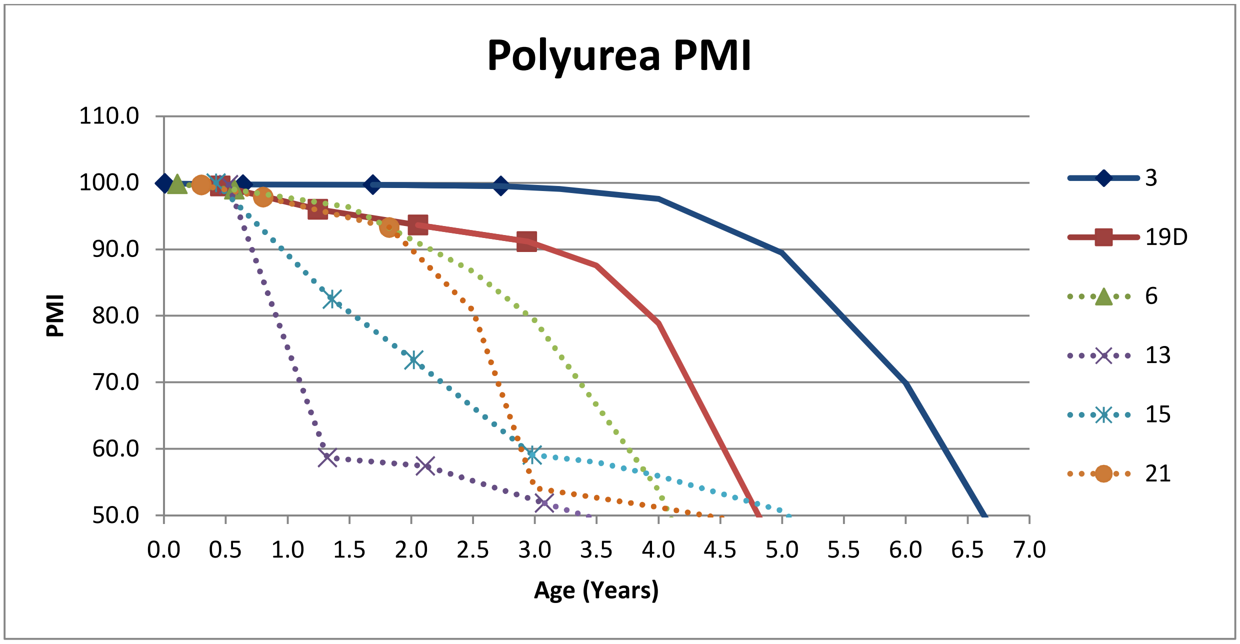


Figure 78. Projected polyurea Pavement Marking Index.
Note: New construction sites are solid lines. Maintenance sites are dotted lines.

The PMI projections are shown in Figure 78. The polyurea ESLs ranged from 1.3 to 3.8 years for maintenance sites and 4.5 to 6.3 years for new construction sites. The early failure of maintenance polyurea sites is attributed to a flaw in the material mix or the inability of polyurea to perform well as a surface application on older pavement. Data from the Illinois Tollway suggests that polyurea should be used for recessed application on new pavement.

3.6. URETHANE

The retroreflectivity projections for the maintenance and new construction urethane sites are presented in Figure 79 and Figure 80, respectively. The projected age at retroreflectivity failure for maintenance sites ranged between 3.7 to 6.0 years. The new construction sites are projected to perform similarly with a range of 3.2 to 6.2 years. The retroreflectivity for Urethane-6, 8, and 10 are expected to last the longest because of their high initial performance and because they are recessed.

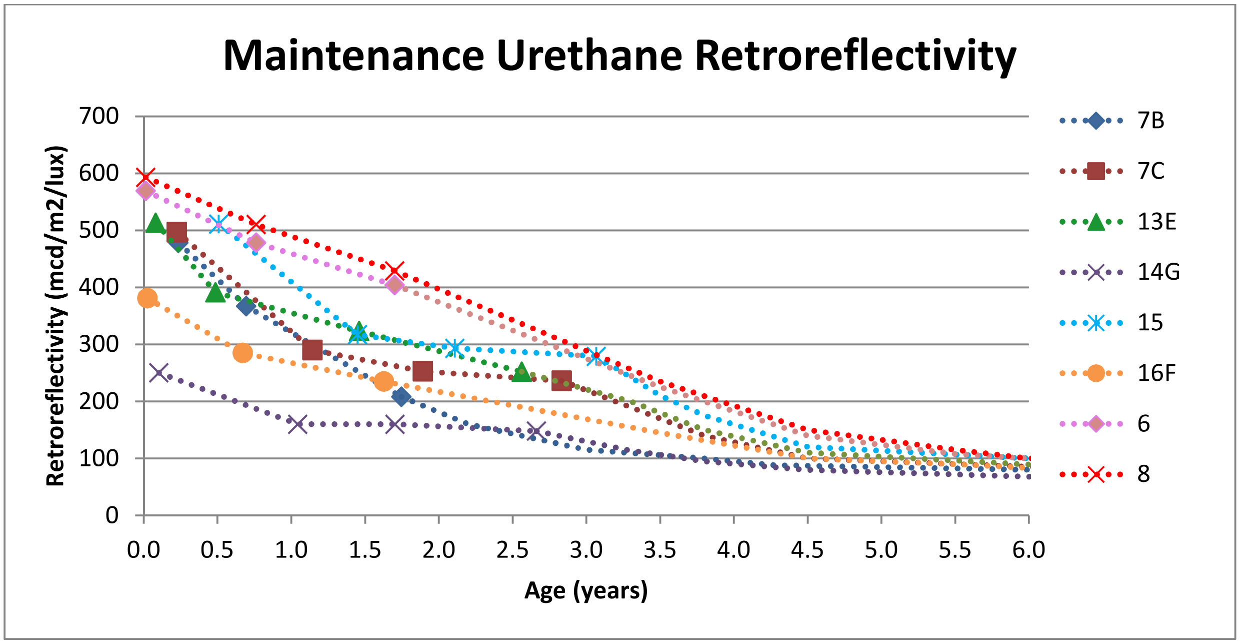


Figure 79. Projected maintenance urethane retroreflectivity.

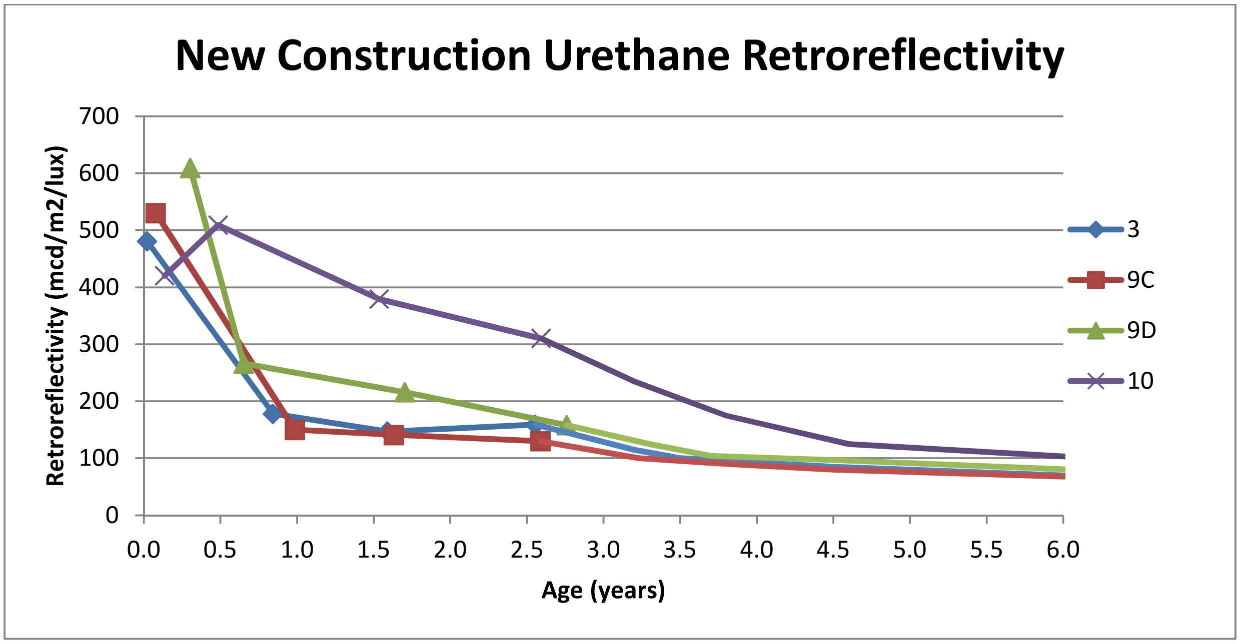


Figure 80. Projected new construction urethane retroreflectivity.

Urethane presence projections are shown in Figure 81 and Figure 82. Surface-applied new construction sites are expected to deteriorate more quickly based on collected data and durability assumptions Urethane-14G percentage missing is expected to increase at a faster rate than most recessed sites because of pavement deterioration. The other four recessed urethane sites are projected to sustain a very good presence for over ten years.

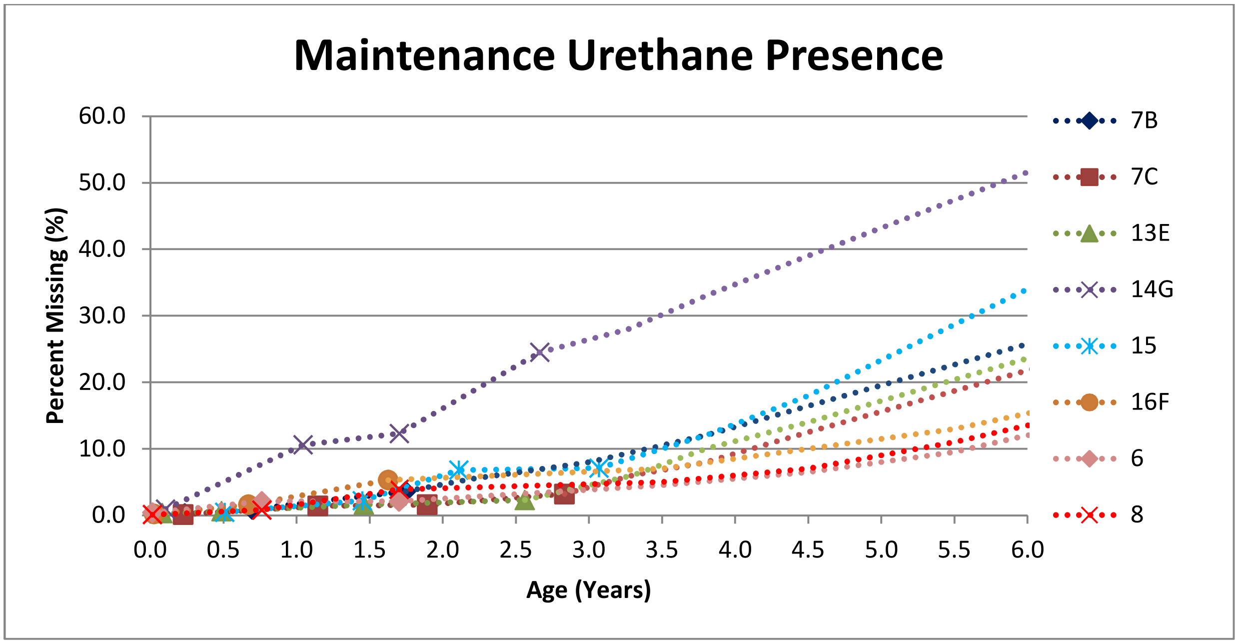


Figure 81. Projected maintenance urethane presence.

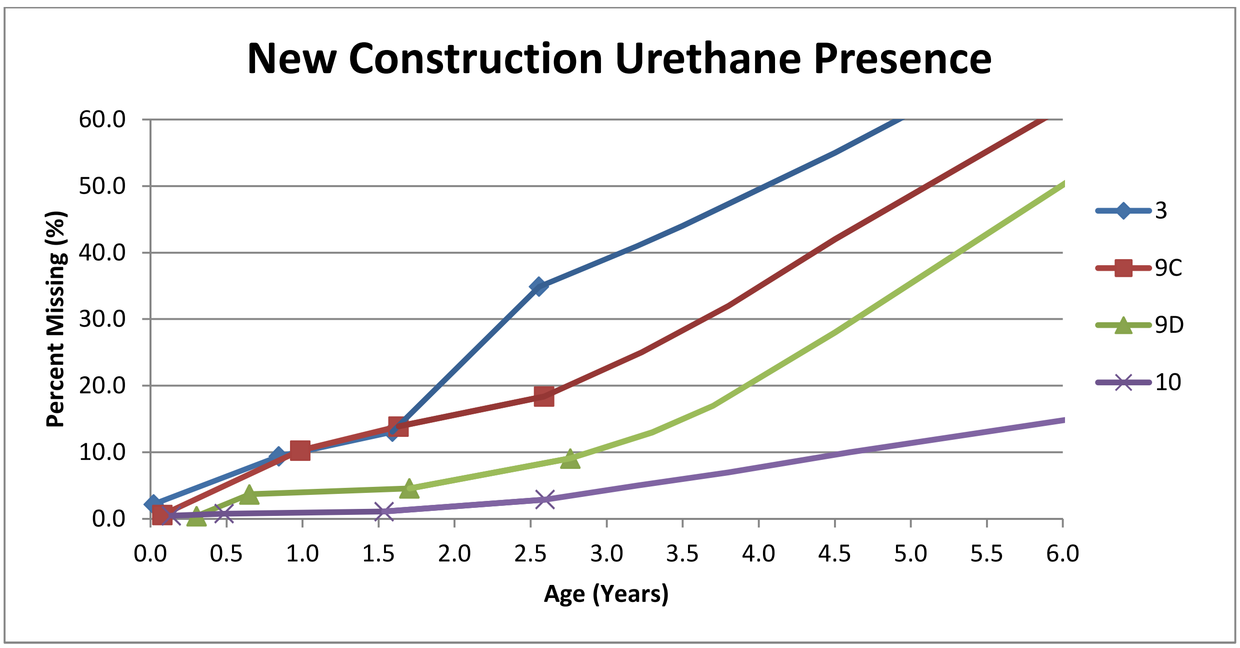


Figure 82. Projected new construction urethane presence.

The projected Pavement Marking Index for maintenance and new construction urethane is presented in Figure 83 and Figure 84, respectively. The ESL for maintenance sites ranged between 3.3 and 5.8 years and between 2.9 and 5.7 years for new construction sites.. The median ESL for all urethane sites was 4.3 years. Therefore, this material seems well suited for maintenance sites that are free from progressive edge line deterioration.

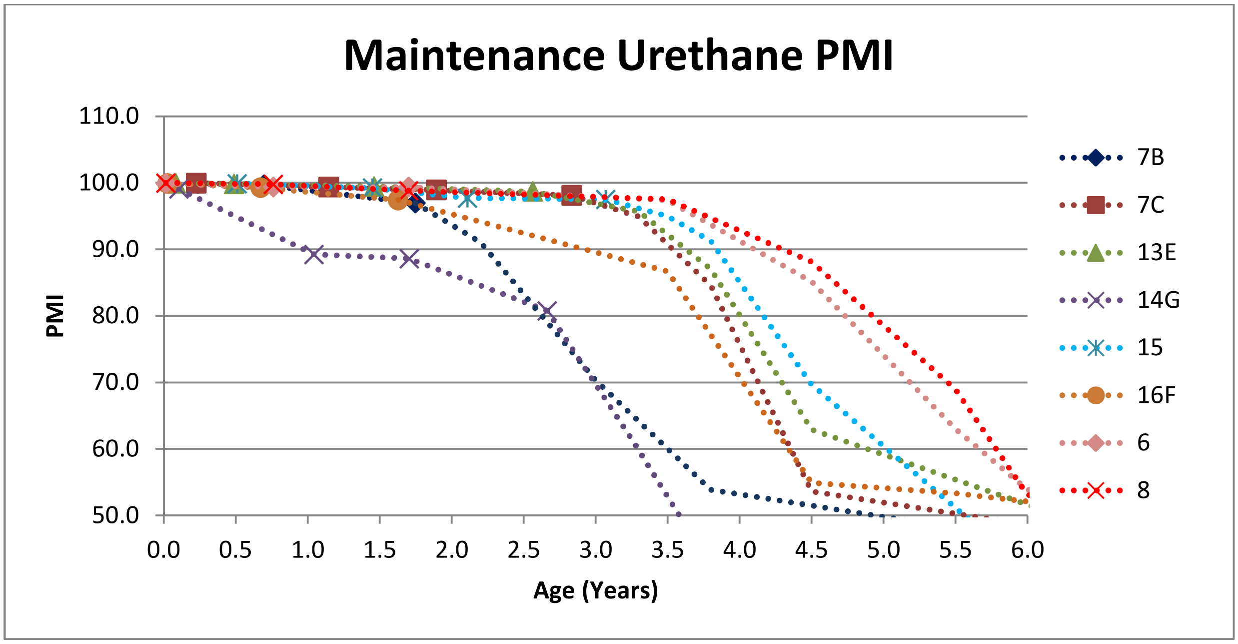


Figure 83. Projected maintenance urethane Pavement Marking Index.

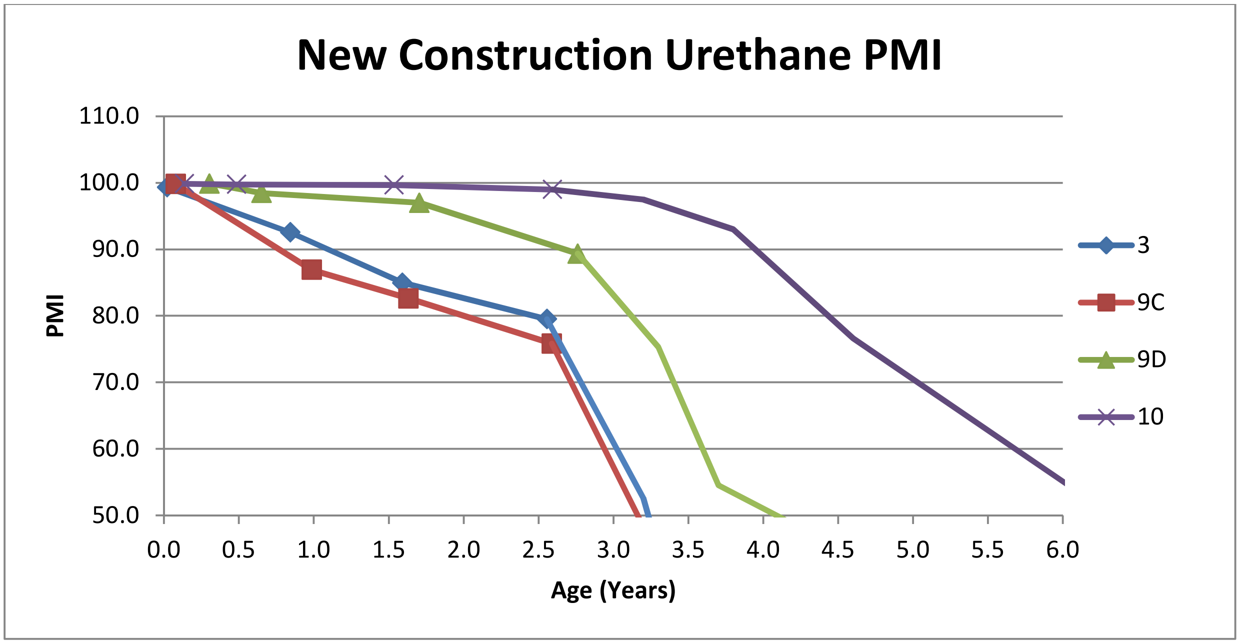


Figure 84. Projected new construction urethane Pavement Marking Index.

CHAPTER 4 SUMMARY

The purpose of this study was to evaluate the performance of pavement markings on both portland cement concrete (PCC) and hot-mix asphalt (HMA) pavements over a period of four years. Field investigations were conducted to gather data on the retroreflectivity and presence of markings and the compatibility between markings and pavement materials. The study implemented ARA's Pavement Marking Index (PMI) as a standard, repeatable metric for incorporating both measured metrics. This method combines both retroreflectivity and presence into one value that represents the overall condition of a pavement marking. A minimum PMI was set to represent the ESL.

A number of the selected test sites were not placed in the first year, 2010, as scheduled; Urethane-6, 8, 16F, and Epoxy-13AH were added after their installation in 2011. Some sites were found to be unsafe for testing, so other sites were added as replacements for the ones that were excluded. Thermo-37A and 37C maintenance sites were restriped in 2011 because of an installation error in 2010; therefore, 2011 data was considered the initial data for these two sites.

Most new construction paint sites were tested twice in 2011: in the early summer to observe the markings after one winter before restriping and in the late fall to observe the markings after a second coat of material was placed. The 2012 early summer collection showed that double-layered markings on new pavement perform better than single-layer installations. Paint-41, a new construction paint with the highest retroreflectivity after one winter, showed that this material could survive a second winter in the southern zone of Illinois and might last a third winter as well. The double layer of Paint-9F was also tested after a second winter and performed very well. Data collected on paint on HMA suggests that the condition of the markings should be evaluated before restriping; at many paint sites on HMA, markings were restriped before they reached their ESL. Based on the performance of Paint-18A, paint is found to be unsuitable for PCC pavement.

The results of thermoplastic indicated good levels of retroreflectivity with the exception of Thermo-37A and 37C. All thermoplastic tests sites were on HMA pavements only. Surface applications and a raised profile are attributes that subject this material to more plow damage. In addition to Urethane-3, Thermo-17 and Thermo-3 showed the highest level of deterioration of presence of the non-paint materials.

Three tape sites were classified among the top five materials for longest projected service life. The sites had high initial retroreflectivity and showed almost no change in presence over the testing period. It was observed that tape performed well on HMA and PCC when properly installed.

Epoxy sites were unintentionally limited to those surface-applied on HMA in Zone 2. These sites experienced a large decrease in retroreflectivity after the first winter and a slight decrease after the second and third winters. The presence of epoxy on the new construction sites deteriorated faster than epoxy on the maintenance site.

The retroreflectivity failure of maintenance Poly-13 and 15 was likely due to poor installation. On the other hand, new construction Poly-3 and 19D had high retroreflectivity. Poly-3, the site with good bead embedment, is expected to have the longest service life of the non-tape materials. Most of the material of Poly-19D, the site with poor pavement preparation, is expected to chip off of the pavement before its retroreflectivity falls below 100 mcd/m^2/lux.

Three recessed urethane sites are expected to have ESLs of 5.7 to 5.8 years. Surface-applied maintenance sites are projected to perform better than surface-applied new construction sites. Pavement type does not appear to affect urethane performance.

For asphalt surfaces, it was observed that the pavement conditions have a great effect on marking life. Deteriorating older pavements will cause the marking to deteriorate as well. Poly-6 and Thermo-7A were restriped before their second winter because of pavement distress. Most maintenance paint sites and Urethane-14G also exhibited progressive pavement distress, thereby lowering the effectiveness of the markings.

From the results of the study and a life-cycle cost analysis, ARA developed a pavement marking selection guide. All data, both measured and projected, contributed to the striping recommendations in the guide. Because the successful performance of a marking depends largely on controlling many variables during the installation of the marking, the guide includes pavement marking installation inspection methods for use by IDOT inspectors.

REFERENCES

Federal Register. Proposed Rules. (FHWA Docket No. FHWA-2009-0139). National Standards for Traffic Control Devices; the Manual on Uniform Traffic Control Devices for Streets and Highways; Maintaining Minimum Retroreflectivity of Longitudinal Pavement Markings. Vol. 75, No. 77. April 22, 2010.

Shahin, M. Y. Pavement Management for Airports, Roads, and Parking Lots. Sec. 3.5 Calculating the PCI. pp. 27-36. 1994.

APPENDIX A FINAL LIST OF TESTED SITES

Table A.1. Final Maintenance Sites

Maintenance		Variables												
Material Types	Test Site #	ADT		Climate			Pavement Type				Surface Application			Installation Date
		Low (≤ 10K)	High (> 10K)	Zone 1 (North IL)	Zone 2 (Central IL)	Zone 3 (South IL)	HMA	PCC	Chip Seal	Micro-Surface	Surface	Recessed Inlay	Recessed Groove	
Paint	13	2200-3650			Peoria									9/1/2010
	21B	4650-5600				Effingham								7/7/2010
	37A		8,300		Peoria									9/1/2010
	37B		16,200		Peoria									9/9/2010
Paint - Double Layer	1A	2,700		Lee										6/3/2011
	9C	4,200			Effingham									6/9/2011
	9F	25			Peoria									7/20/2011
	12	1100			Springfield									8/8/2011
	17B	4,200												8/9/2011
Thermoplastic	7A	1800		Henry										6/17/2010
	7B	7700		Whiteside										6/24/2010
	29		13,000	Lee										6/30/2010
Thermo-Double Layer	37A		19,500		Piatt									7/18/2011
	37C		28,800		Champaign									7/18/2011
Polyurea	6		17700-30300	Ogle										9/17/2010
	13		28800-54300		Champaign									5/3/2010
	15		20000+		McLean									6/7/2010
	21		13,500		Effingham									6/29/2010
Urethane	7B		13,000	Lee										8/2/2010
	7C		10,200	Whiteside										8/5/2010
	13E		9700-14600		Peoria									11/1/2010
	14G		25000-27700		McLean									10/1/2010
	15		12000+		McLean									5/6/2010
	16F		14700-17200		Woodford									10/18/2011
	6		11,600	Whiteside										9/22/2011
	8		11,600	Whiteside										9/22/2011
Epoxy	13AH		2150-5300		Woodford									6/22/2011

*Test site numbers highlighted in green indicate that the sites were tested for the first time in 2011

Table A.2. Final New Construction Sites

New Construction		Variables												
Material Types	Test Site #	ADT		Climate			Pavement Type				Surface Application			Installation Date
		Low (≤ 10K)	High (> 10K)	Zone 1 (North IL)	Zone 2 (Central IL)	Zone 3 (South IL)	HMA	PCC	Chip Seal	Micro-Surface	Surface	Recessed In-lay	Recessed Groove	
Paint	1A	2,700		Lee										8/10/2010
	9C	4,200			Effingham									7/10/2010
	9F	25			Peoria									8/10/2010
	12	1100			Springfield									11/1/2010
	17B	4,200				Franklin								7/10/2010
	18A	1,060				Franklin								9/10/2010
	41		8600			Jefferson								11/10/2010
Thermoplastic	1B		22,400			Madison								11/10/2010
	3	7500		Stephenson										11/10/2010
	9C	5,150			Madison									8/10/2010
	17B	2,800				Washington								7/10/2010
	17C	12200				Marion								7/10/2010
	25		91,000	Will			SMA							9/10/2010
	33B		12,000		Effingham									7/10/2010
	35B		20,350		Champaign									10/25/2010
	41		49,400			Madison								9/10/2010
Tape	1		91,000	Will			SMA							9/10/2010
	7		65,000	DuPage										6/1/2007
	8		65,000	DuPage										6/1/2007
	10A		5000		Woodford									10/10/2010
	10B		20,350		Champaign									10/25/2010
	17		var. 16,850-33,000			Franklin								9/1/2010
	23		31500-56100			St. Clair								9/1/2009
	25		7000	Lee										9/1/2009
Epoxy	1		7000	Lee										12/1/2005
	2A		25,000	Winnebago			SMA							10/1/2009
	2B		65,000	DuPage										10/1/2008
	4		60,000	DuPage										6/1/2007
	9A		5000		Woodford									11/10/2010
	9B		9,400		Peoria									11/1/2010

*Test site numbers highlighted in red indicate Illinois Tollway test sites

(continued, next page)

Table A.2. Final New Construction Sites (continued)

New Construction		Variables												
Material Types	Test Site #	ADT		Climate			Pavement Type				Surface Application			Installation Date
		Low (≤ 10K)	High (> 10K)	Zone 1 (North IL)	Zone 2 (Central IL)	Zone 3 (South IL)	HMA	PCC	Chip Seal	Micro-Surface	Surface	Recessed Inlay	Recessed Groove	
Polyurea	1B		7000	Lee										12/1/2005
	2A		7000	Lee										12/1/2005
	3		22,100	Will										11/1/2010
	4A		65,000	DuPage										6/1/2007
	4B		65,000	DuPage										6/1/2007
	4C		65,000	DuPage										6/1/2007
	19D		2350			Madison								6/1/2010
	25A		65,000	DuPage										6/1/2010
	25B		65,000	DuPage										6/1/2010
	26		7000	Lee										12/1/2005
Urethane	3		8900	Jo Daviess										11/24/2010
	9C		7700		Woodford									11/1/2010
	9D		32,800		Sangamon									8/10/2010
	10		11,800		Sangamon									10/10/2010

*Test site numbers highlighted in red indicate Illinois Tollway test sites

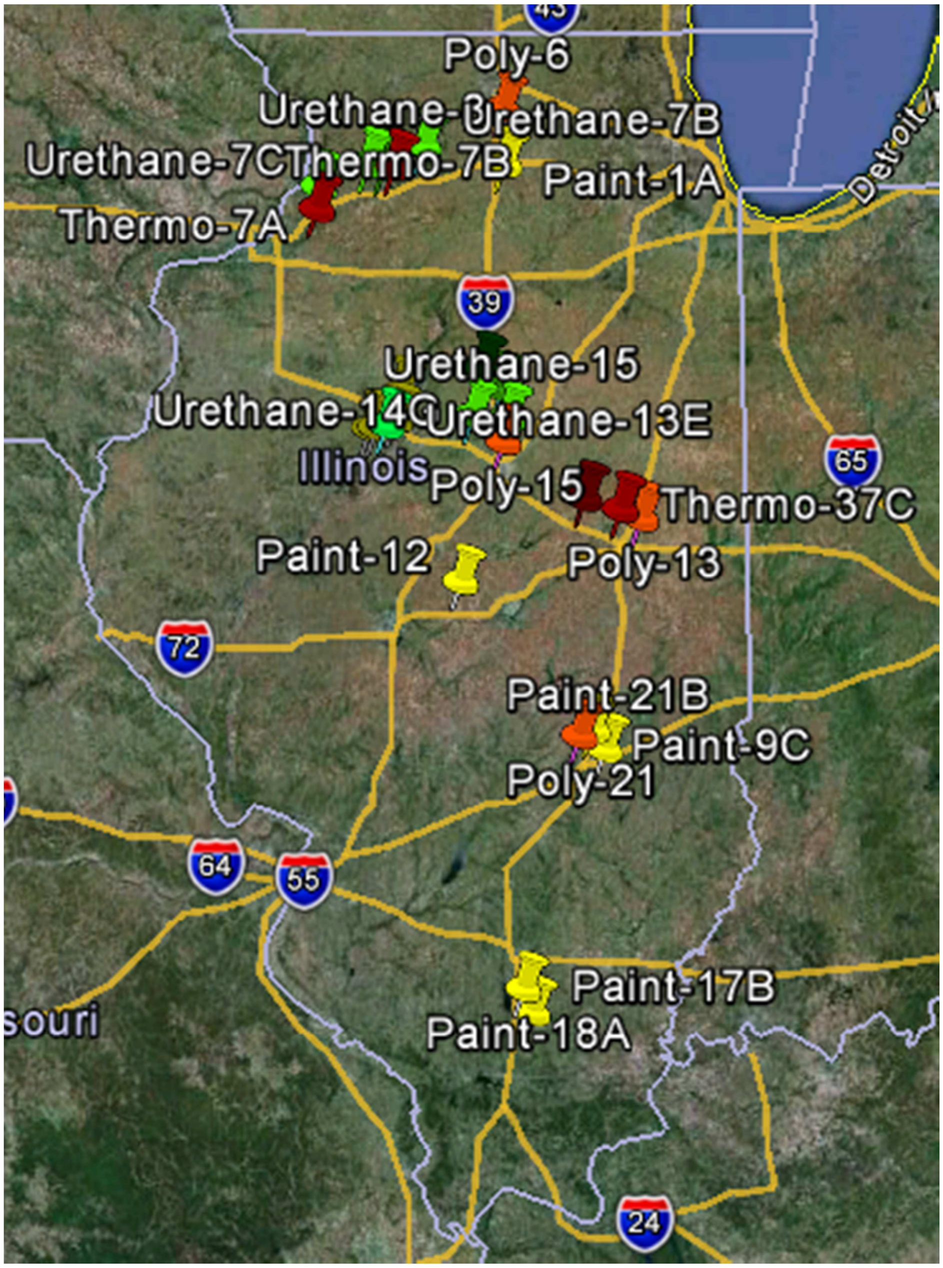


Figure A.1. Final map of tested maintenance sites.

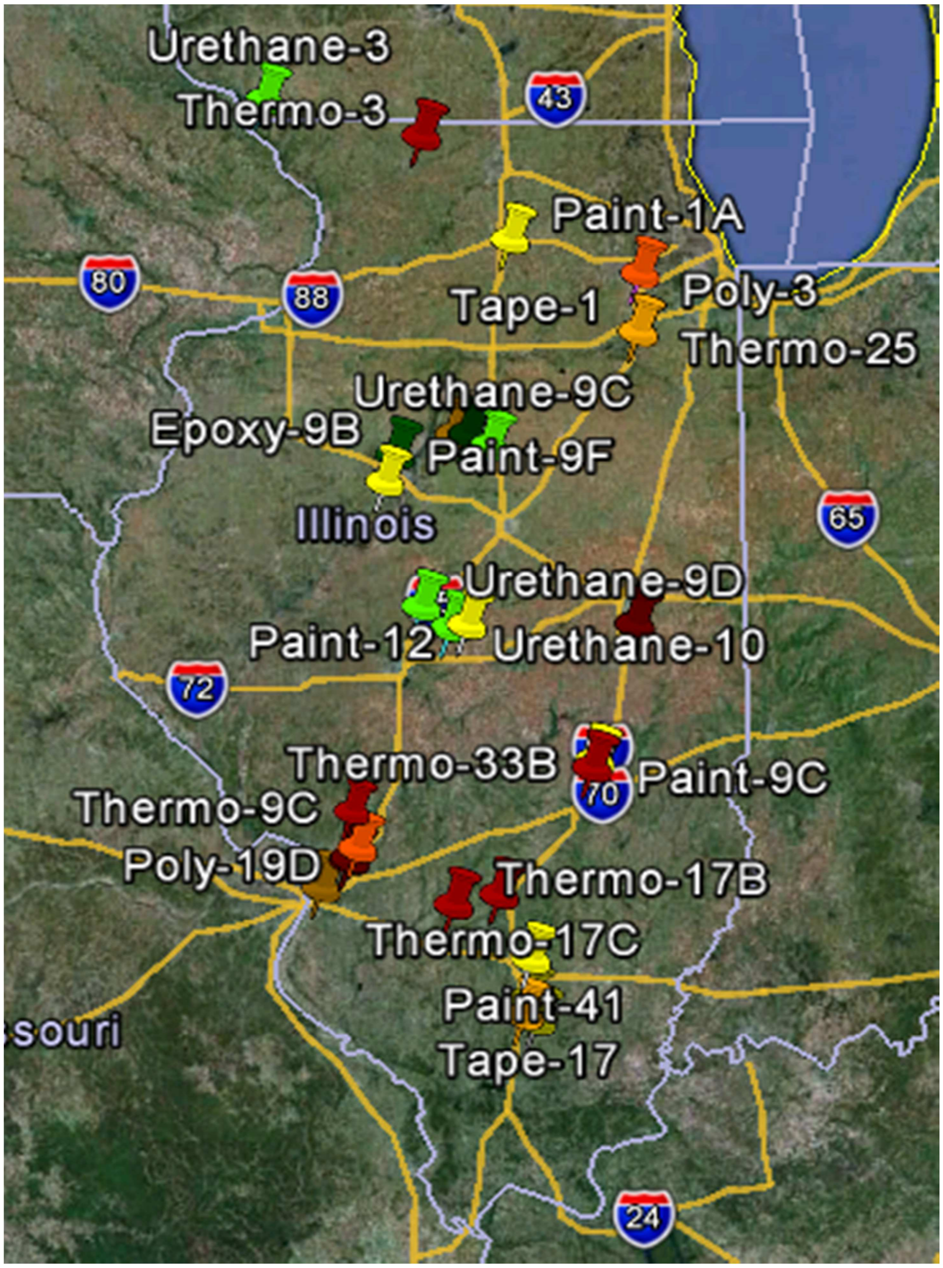


Figure A.2. Final map of tested new construction sites.

APPENDIX B ILLINOIS TOLLWAY DATA

Table B.1. Illinois Tollway Retroreflectivity Data

Site Name	Average Dry Retroreflectivity												
	I-88 Dixon installed 10/1/2005												
	Test Date:	12/22/2005	3/20/2006	5/25/2006	11/2/2006	5/4/2007	10/24/2007	6/13/2008	10/22/2008	6/10/2009	10/27/2009	11/3/2010	6/29/2011
	Age:	0.22	0.47	0.65	1.09	1.59	2.06	2.70	3.06	3.69	4.07	5.09	5.75
Epoxy-1		128	204	196	170	144	127	120	94	110	80	66	62
Tape-25		308	572	493	402	397	405	113	119	119	102	109	**
Poly-1B		286	377	347	313	259	186	117	104	98	78	68	59
Poly-26		780	832	750	712	634	523	428	393	395	316	321	**
Poly-2A		454	831	735	718	610	609	431	400	391	295	296	**
	I-88 Naperville installed 5/1/2007												
	Test Date:	5/15/2007	6/15/2007	10/15/2007	5/12/2008	10/1/2008	4/9/2009	10/13/2009	7/15/2010	6/25/2011	5/12/2012	6/21/2013	
	Age:	0.04	0.12	0.46	1.03	1.42	1.94	2.45	3.21	4.15	5.04	6.15	
Poly-25A		853	420	278	276	280	262	248	225	213	208	182	
Epoxy-4		414	571	636	508	484	412	367	316	300	278	247	
Poly-4A		683	476	525	390	341	314	248	247	220	188	180	
Poly-4B		308	544	462	381	320	277	263	231	202	183	175	
Poly-4C		949	738	611	384	339	281	256	224	206	211	204	
Tape-8		637	712	728	799	801	508	411	248	147	150	163	
Tape-7		1128	1127	1023	282	225	151	160	161	161	167	180	
Poly-25B		728	628	567	506	476	345	-	-	-	-	-	
	I-90 Rockford Site installed 10/1/2009												
	Test Date:	10/21/2009	11/3/2010	7/12/2011	5/11/2012	6/18/2013							
	Age:	0.05	1.09	1.78	2.61	3.72							
Epoxy-2A		534	346	313	297	294							
	I-355 Downers Grove installed 10/1/2008												
	Test Date:	10/9/2009	11/10/2010	6/28/2011	5/9/2012	7/12/2013							
	Age:	1.02	2.11	2.74	3.61	4.78							
Epoxy-2B		333	265	258	227	200							

**Restriped before 2011 testing

Table B.2. Illinois Tollway Presence Data

Site Name	Average Percentage Missing					
	I-88 Dixon installed 10/1/2005					
	Test Date:	6/10/2009	11/3/2010	6/29/2011		
	Age:	3.69	5.09	5.75		
Epoxy-1		25.2	49.9	56.4		
Tape-25		3.9	13.6	**		
Poly-1B		28.6	55.2	63.8		
Poly-26		2.7	7.8	**		
Poly-2A		7.1	10.3	**		
	I-88 Naperville installed 5/1/2007					
	Test Date:	10/13/2009	7/15/2010	6/25/2011	5/12/2012	6/21/2013
	Age:	2.45	3.21	4.15	5.04	6.15
Poly-25A		*	*	*	*	*
Epoxy-4		1	1.9	2.4	2.6	3.3
Poly-4A		1.3	2.3	3.6	3.7	5.6
Poly-4B		*	*	*	*	*
Poly-4C		*	*	*	*	*
Tape-8		0.1	0.2	0.3	0.4	0.7
Tape-7		*	*	*	*	*
Poly-25B		0.9	*	*	*	*
	I-90 Rockford Site installed 10/1/2009					
	Test Date:	10/21/2009	11/3/2010	7/12/2011	5/11/2012	6/18/2013
	Age:	0.05	1.09	1.78	2.61	3.72
Epoxy-2A		1.8	2.9	3.7	4.0	4.9
	I-355 Downers Grove installed 10/1/2008					
	Test Date:	10/9/2009	11/10/2010	6/28/2011	5/9/2012	7/12/2013
	Age:	1.02	2.11	2.74	3.61	4.78
Epoxy-2B		0.8	3.4	4.3	7.2	8.1

* Photographs were collected but not processed with MarkAnalysis software

**Restriped before 2011 testing

APPENDIX C PROJECTED AGE AT FAILURE

Site Name	Striping Contract	ADT	Zone #	Pavement Type	Application	Projected Age at Failure (years)		
						Retroreflectivity	Presence	PMI
Paint-13	Maintenance	2200-3650	2	HMA	Surface	1.5	3.8	1.4
Paint-21B	Maintenance	4650-5600	3	HMA	Surface	1.4	4.2	1.4
Paint-37A	Maintenance	8,300	2	HMA	Surface	1.3	3.0	1.0
Paint-37B	Maintenance	16,200	2	HMA	Surface	1.2	3.1	1.0
Paint-1A	New Const.	2,700	1	HMA	Surface	2.1	3.3	1.9
Paint-9C	New Const.	4,200	2	HMA	Surface	1.5	3.5	1.4
Paint-9F	New Const.	25	2	HMA	Surface	1.8	3.8	1.6
Paint-12	New Const.	1,100	2	Micro-Surface	Surface	1.7	2.9	1.4
Paint-17B	New Const.	4,200	3	HMA	Surface	2.2	3.2	1.8
Paint-18A	New Const.	1,060	3	PCC	Surface	**	0.6	0.6
Paint-41	New Const.	8,600	3	HMA	Surface	2.6	3.6	2.4
Paint-1A	Double Layer	2,700	1	HMA	Surface	2.8	4.1	2.6
Paint-9C	Double Layer	4,200	2	HMA	Surface	2.3	4.5	2.2
Paint-9F	Double Layer	25	2	HMA	Surface	2.6	4.9	2.5
Paint-12	Double Layer	1,100	2	Micro-Surface	Surface	2.6	4.3	2.4
Paint-17B	Double Layer	4,200	3	HMA	Surface	3.0	4.7	2.8
Thermo-7A	Maintenance	1,800	1	HMA	Surface	5.0	8.8	4.7
Thermo-7B	Maintenance	7,700	1	HMA	Surface	5.0	9.0	4.7
Thermo-29	Maintenance	13,000	1	HMA	Surface	4.3	6.3	3.8
Thermo-37A	Double Layer	19,500	2	HMA	Recessed	3.6	8.0	3.2
Thermo-37C	Double Layer	28,800	2	HMA	Recessed	3.2	8.1	2.7
Thermo-3	New Const.	7500	1	HMA	Surface	4.3	4.8	3.6
Thermo-9C	New Const.	5,150	2	HMA	Surface	5.0	9.2	4.7
Thermo-17B	New Const.	2,800	3	HMA	Surface	6.5	8.0	5.6
Thermo-17C	New Const.	12,200	3	HMA	Surface	6.0	5.1	4.2
Thermo-25	New Const.	91,000	1	SMA	Surface	4.4	7.0	4.2
Thermo-33B	New Const.	12,000	2	HMA	Surface	4.3	8.9	4.1
Thermo-35B	New Const.	20,350	2	HMA	Surface	4.0	8.8	3.8
Thermo-41	New Const.	49,400	3	HMA	Surface	6.0	8.3	5.5
Thermo-1B	New Const.	22,400	3	Micro-Surface	Surface	5.0	9.0	4.7
Tape-1	New Const.	91,000	1	SMA	Surface	3.5	> 10	3.4
Tape-10A	New Const.	5,000	2	HMA	Inlay	4.5	> 10	4.5

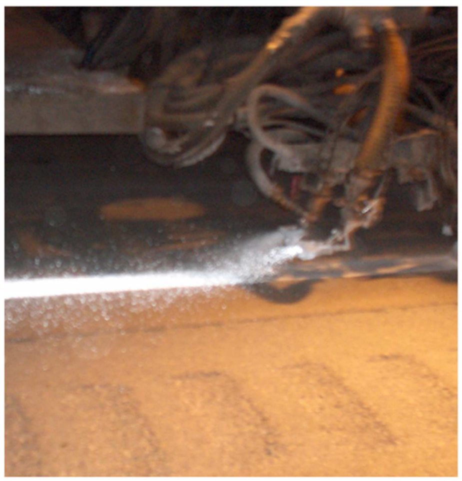
(continued, next page)

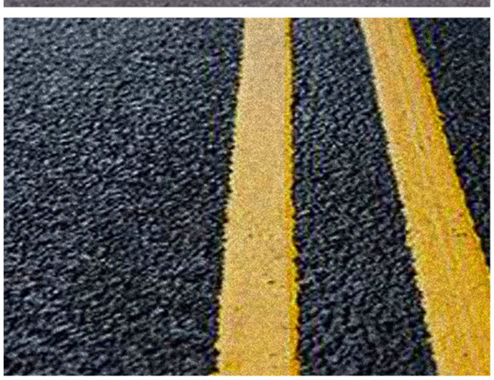
Site Name	Striping Contract	ADT	Zone #	Pavement Type	Application	Projected Age at Failure (years)		
						Retroreflectivity	Presence	PMI
Tape-10B	New Const.	20,350	2	HMA	Inlay	6.7	> 10	6.7
Tape-17	New Const.	16,850-33,000	3	HMA	Inlay	6.0	> 10	5.8
Tape-23	New Const.	31,500-56,100	3	PCC	Grooved	6.8	> 10	6.8
Epoxy-9A	New Const.	5,000	2	HMA	Surface	4.3	5.8	3.8
Epoxy-9B	New Const.	9,400	2	HMA	Surface	3.9	5.0	3.5
Epoxy-13AH	Maintenance	2,150-5,300	2	HMA	Surface	4.3	7.5	4.0
Poly-6	Maintenance	17,700-30,300	1	HMA	Recessed	4.8	5.2	3.8
Poly-13	Maintenance	28,800-54,300	2	HMA	Surface	1.3	6.5	1.3
Poly-15	Maintenance	20,000+	2	PCC	Surface	2.9	7.5	2.9
Poly-21	Maintenance	13,500	2	HMA	Surface	3.0	9.3	2.9
Poly-3	New Const.	22,100	1	PCC	Surface	7.0	8.0	6.3
Poly-9	New Const.	10,475	2	HMA	Surface	**	**	**
Poly-19D	New Const.	2,350	3	PCC	Surface	7.0	5.5	4.5
Urethane-7B	Maintenance	13,000	1	PCC	Surface	3.8	> 10	3.5
Urethane-7C	Maintenance	10,200	1	PCC	Surface	4.5	> 10	4.4
Urethane-13E	Maintenance	9,700-14,600	2	HMA	Surface	5.2	> 10	4.9
Urethane-14G	Maintenance	25,000-27,700	2	HMA	Recessed	3.7	6.4	3.3
Urethane-15	Maintenance	12,000+	2	PCC	Surface	6.0	8.0	5.0
Urethane-16F	Maintenance	14,700-17,200	2	PCC	Recessed	4.5	> 10	4.3
Urethane-6	Maintenance	11,600	1	HMA	Recessed	6.0	> 10	5.7
Urethane-8	Maintenance	11,600	1	PCC	Recessed	6.0	> 10	5.8
Urethane-3	New Const.	8,900	1	PCC	Surface	3.5	4.5	3.0
Urethane-9C	New Const.	7,700	2	HMA	Surface	3.2	5.5	2.9
Urethane-9D	New Const.	32,800	2	HMA	Surface	4.2	6.3	3.6
Urethane-10	New Const.	11,800	2	HMA	Recessed	6.2	> 10	5.7

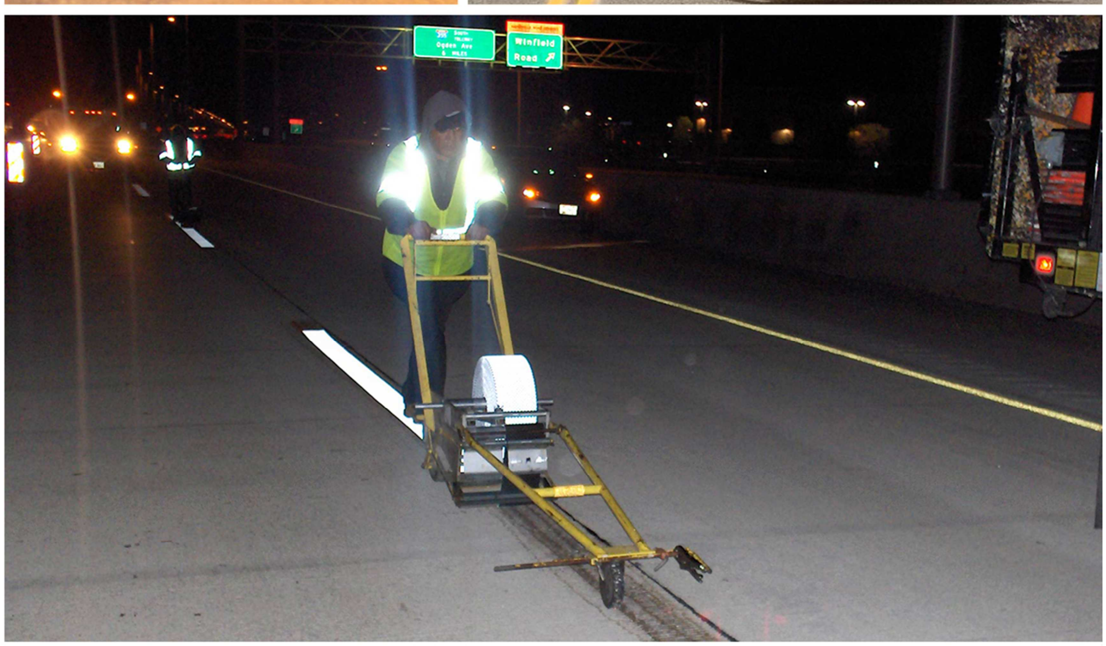
** Insufficient data available

Illinois Department of Transportation

Pavement Marking Selection Guide







Developed by ARA

Publication Date: December 2013

Purpose

This guide serves as both a reference for selecting optimum marking materials and as a reference for inspecting the installation of markings. The guide is intended for use in design, maintenance, and inspection.

History

This guide is a product of an Illinois Center for Transportation (ICT) research project. The project, ICT R27-77, “Evaluating Pavement Markings on Portland Cement Concrete and Various Asphalt Surfaces,” was conducted by Applied Research Associates, Inc. (ARA) and guided by a Technical Review Panel (TRP) consisting of members of the Illinois Department of Transportation (IDOT), the Illinois Tollway, and industry. A copy of the final report can be found on the ICT website: http://www.ict.illinois.edu (click on the “Research” tab at the top of the page, then from the drop-down menu, select “Publications” and search for project R27-77).

Disclaimer

This is a new guide and does not replace any existing documents. The guide does not constitute a standard, specification, or regulation.

Contact

Questions concerning information in the guide should be addressed to the Bureau of Materials and Physical Research (BMPR) at 217-782-7200.

Contents

SECTION 1 INTRODUCTION

Pavement markings provide critical information to motorists. With the wide variety of marking materials available, choosing the material that best meets the needs of the public can be challenging. The purpose of this guide is to serve as a reference for selecting optimum pavement marking materials for different site criteria. Optimum marking materials are those that are compatible with the site, provide an appropriate service life, and are cost effective. Section 2 of the guide describes the various factors that influence the performance of pavement markings and then, based on these variables, presents matrices of recommended materials.

Because the successful performance of a marking depends on proper installation, section 3 is included as a reference for inspecting the installation of markings. That section contains installation inspection checklists for each of the marking types approved by the Illinois Department of Transportation (IDOT) at the time of this guide's publication. Currently approved marking materials and their performance criteria are described in IDOT's Standard Specifications for Road and Bridge Construction.

This guide is intended for use by design personnel, maintenance personnel, and field inspectors. It provides a single reference for all personnel so that the benefits from pavement marking research and best practices can be standardized across the state.

SECTION 2 MATERIAL SELECTION

2.1 Performance Factors

Many different materials can be used for pavement markings, and the service life and cost of the materials vary greatly. Some materials are more appropriate for a given location than other materials, and the performance of a pavement marking material can vary widely based on many factors. Installation factors that influence performance are covered in section 3, and major factors that affect performance post-installation are:

- Environmental conditions
- Roadway surface type
- Traffic volume

The greatest factor affecting the performance of pavement markings in Illinois is abrasion from snow removal. This is evidenced by the fact that markings in the northern part of the state deteriorate more rapidly than those in the southern part of the state. Illinois is more than 380 miles long from its northern border to its southernmost tip, and because of this range in latitude, the amounts of snowfall vary considerably. Figure 1 is a contour map displaying the average number of days with snowfall at or above 1 inch in Illinois. Many regions of the country with heavy snowfall choose to recess pavement markings (place them in shallow grooves) to keep snowplow blades off the markings. Installing the groove is an added expense, but the extended life of the marking often offsets the cost of the groove.

The pavement surface type, hot-mix asphalt (HMA) or Portland cement concrete (PCC), can affect the bonding characteristics of marking materials. Therefore, markings can have different service lives depending on the surface on which they are placed.

Traffic volume can also influence the performance of a pavement marking. The service lives of pavement marking materials decrease when exposed to higher traffic volumes. For this reason, more durable markings are often considered for roadways with higher average annual daily traffic (AADT).

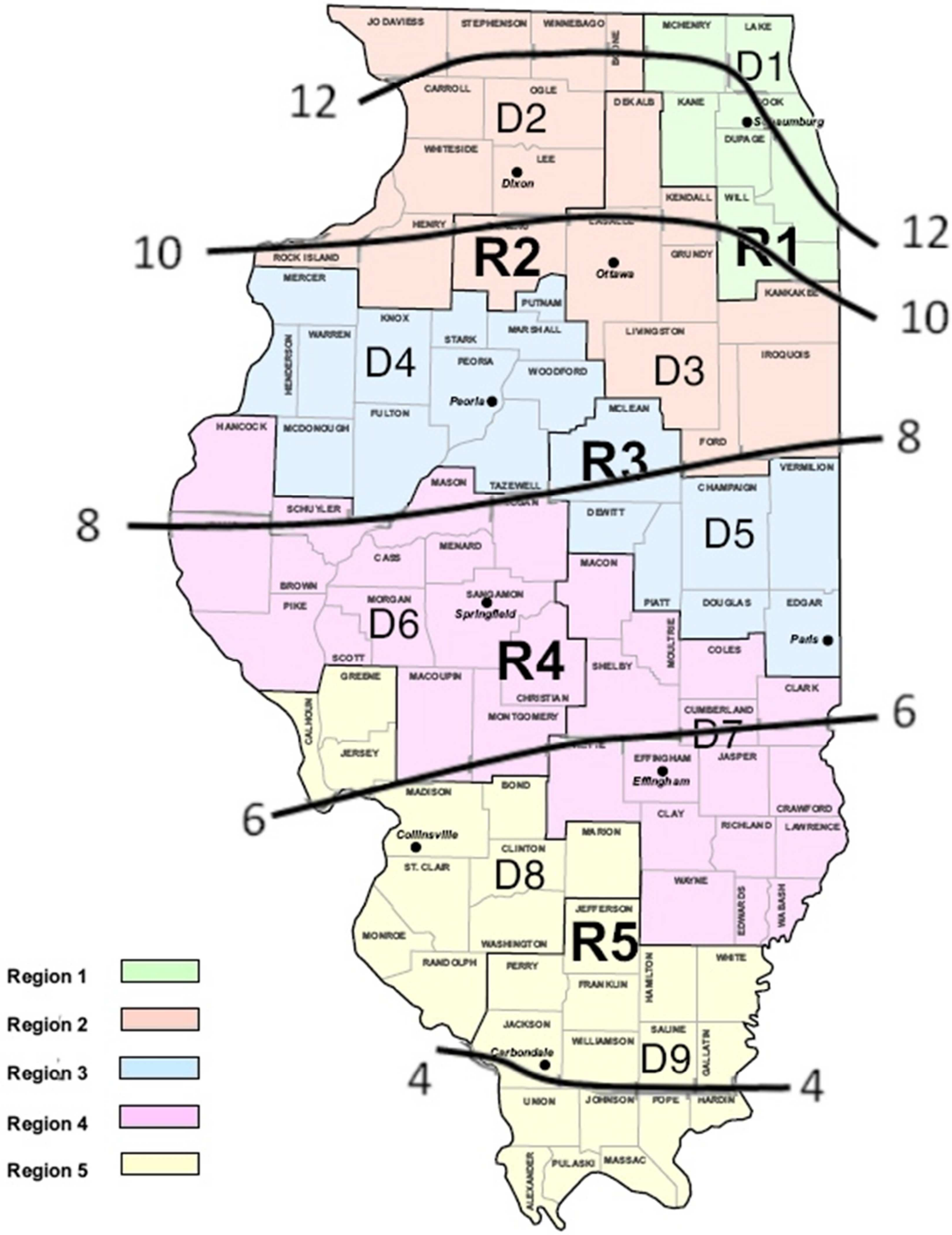


Figure 1. Average number of days with snowfall at or above 1 inch.

2.2 Material Recommendations

Because of the varied environmental conditions in Illinois, the recommendations in this guide separate the state into three climatic zones: Northern, Central, and Southern. The Northern Zone includes areas north of Interstate 80, which closely follows the contour line in Figure 1 for 10 days per year at or above 1 inch of snowfall. The Central Zone is the area between Interstate 80 and Interstate 70, which closely follows the contour line for 6 days at or above 1 inch of snowfall. The Southern Zone is the area of the state south of Interstate 70.

At the time of this guide's publication, the IDOT-approved permanent pavement marking materials for long line application were:

- Thermoplastic
- Water-based paint
- Preformed plastic (tape), Type B
- Epoxy
- Polyurea
- Modified urethane

New materials and formula modifications to existing materials frequently become available. Therefore, such materials may be used on an experimental basis with approval from the Bureau of Materials and Physical Research (BMPR).

When considering marking materials for maintenance striping (restriping), it is important to note that not all material types are compatible with one another. Some materials will adhere to existing materials of another type, and others will adhere only to existing materials of the same type. When a marking is not compatible as the restripe material, then the existing material must be removed. Even when marking materials are compatible, the existing material must still be bonded well to the pavement; loose material should be removed during surface preparation. Table 1 summarizes the compatibility of marking materials for maintenance striping.

Table 1. Matrix of marking material compatibility for restriping.

Existing Material	Restripe Material					
	Thermoplastic	Water-Based Paint	Preformed Plastic, Type B	Epoxy	Polyurea	Modified Urethane
Thermoplastic	Y	Y	N	N	N	N
Water-Based Paint	N	Y	N	N	N	N
Preformed Plastic, Type B	N	N	N	N	N	N
Epoxy	N	Y	N	Y	N	N
Polyurea	N	Y	N	N	Y	N
Modified Urethane	N	Y	N	N	N	Y

Marking material recommendations are presented in Tables 2 through 5. Tables 2 and 3 are material options for maintenance striping on HMA and PCC pavements, respectively. Tables 4 and 5 are options for markings on newly constructed HMA and PCC, respectively. Within each block of the tables, the highest recommended material is listed first. Recommendations are based on expected service life and contracted cost of installation. In parentheses following each material type is the expected service life (in years) and the equivalent uniform annual cost of the material. This information is provided to aid users in their selection decisions. IDOT maintenance crews annually perform a portion of paint maintenance striping, and users should note that the installed cost of these in-house markings may cost less than the contracted costs shown in Table 2.

Table 2. Pavement marking material recommendations for maintenance striping on HMA.

MAINTENANCE STRIPING ON HMA					
Zone	AADT	Pavement Service Life ≤ 5 years [1]		Pavement Service Life > 5 years	
		Surface	Recessed [2]	Surface	Recessed [2]
Northern IL	Low (≤ 7000)	Thermoplastic (3-4, $0.35-$0.27) Paint (1-2, $0.77-$0.39)	Thermoplastic (5, $0.22) Epoxy (5, $0.33)	Thermoplastic (3-4, $0.35-$0.27) Paint (1-2, $0.77-$0.39)	Thermoplastic (6-7, $0.18-$0.16) Epoxy (6-8, $0.28-$0.21)
	High (> 7000)	Thermoplastic (3-4, $0.35-$0.27) Paint (1-2, $0.77-$0.39) Epoxy (2-3, $0.78-$0.53) Polyurea (3-4, $0.80-$0.61) Urethane (2-3, $1.05-$0.71)	Thermoplastic (5, $0.22) Epoxy (5, $0.33) Urethane (5, $0.44) Polyurea (5, $0.49)	Thermoplastic (3-4, $0.35-$0.27) Paint (1-2, $0.77-$0.39) Epoxy (2-3, $0.78-$0.53) Polyurea (3-4, $0.80-$0.61) Urethane (2-3, $1.05-$0.71)	Thermoplastic (6-7, $0.18-$0.16) Epoxy (6-8, $0.28-$0.21) Polyurea (7-9, $0.36-$0.29) Urethane (5-6, $0.44-$0.37)
Central IL	Low (≤ 7000)	Thermoplastic (4-5, $0.27-$0.22) Paint (1.5-2, $0.52-$0.39)	Thermoplastic (5, $0.22) Epoxy (5, $0.33)	Thermoplastic (4-5, $0.27-$0.22) Paint (1.5-2, $0.52-$0.39)	Thermoplastic (6-8, $0.18-$0.14) Epoxy (7-9, $0.24-$0.19)
	High (> 7000)	Thermoplastic (4-5, $0.27-$0.22) Epoxy (3-4, $0.53-$0.40) Paint (1-2, $0.77-$0.39) Urethane (3-4, $0.71-$0.54) Polyurea (3-4, $0.80-$0.61)	Thermoplastic (5, $0.22) Epoxy (5, $0.33) Urethane (5, $0.44) Polyurea (5, $0.49)	Thermoplastic (4-5, $0.27-$0.22) Epoxy (3-4, $0.53-$0.40) Urethane (3-4, $0.71-$0.54) Paint (1-2, $0.77-$0.39) Polyurea (3-4, $0.80-$0.61)	Thermoplastic (6-8, $0.18-$0.14) Epoxy (7-9, $0.24-$0.19) Polyurea (7-9, $0.36-$0.29) Urethane (6-7, $0.37-$0.32)
Southern IL	Low (≤ 7000)	Thermoplastic (5, $0.22) Paint (1.5-3, $0.52-$0.27)	Thermoplastic (5, $0.22) Epoxy (5, $0.33)	Thermoplastic (5-6, $0.22-$0.18) Paint (1.5-3, $0.52-$0.27)	Thermoplastic (7-9, $0.16-$0.13) Epoxy (7-9, $0.24-$0.19)
	High (> 7000)	Thermoplastic (5, $0.22) Paint (1.5-3, $0.52-$0.27) Epoxy (3-4, $0.53-$0.40) Urethane (4-5, $0.54-$0.44) Polyurea (4-5, $0.61-$0.49)	Thermoplastic (5, $0.22) Epoxy (5, $0.33) Urethane (5, $0.44) Polyurea (5, $0.49)	Thermoplastic (5-6, $0.22-$0.18) Paint (1.5-3, $0.52-$0.27) Epoxy (3-4, $0.53-$0.40) Urethane (4-5, $0.54-$0.44) Polyurea (4-5, $0.61-$0.49)	Thermoplastic (7-9, $0.16-$0.13) Epoxy (7-9, $0.24-$0.19) Polyurea (8-10, $0.32-$0.26) Urethane (6-8, $0.37-$0.28)

Recommendations shown are:

Material Type (expected service life, equivalent uniform annual cost per foot for a 4-inch-wide marking)

Costs are based on 2013 average unit prices and a 3% discount rate.

Notes:
1 Pavement marking service life is capped at the pavement service life (5 years).
2 Costs shown are for placing materials in existing grooves. Do not install new grooves for maintenance striping on HMA.

Table 3. Pavement marking material recommendations for maintenance striping on PCC.

MAINTENANCE STRIPING ON PCC					
Zone	AADT	Pavement Service Life ≤ 10 years		Pavement Service Life > 10 years	
		Surface	Recessed [1]	Surface	Recessed [2]
Northern IL	Low (≤ 7000)	Epoxy (3-4, $0.53-$0.40) Polyurea (3-4, $0.80-$0.61)	Epoxy (7-9, $0.24-$0.19) Polyurea (7-9, $0.36-$0.29)	Epoxy (3-4, $0.53-$0.40) Polyurea (3-4, $0.80-$0.61)	Epoxy (7-9, $0.24-$0.19, $0.36-$0.29) Polyurea (7-9, $0.36-$0.29, $0.48-$0.39)
	High (> 7000)	Epoxy (3-4, $0.53-$0.40) Polyurea (3-4, $0.80-$0.61) Urethane (2-3, $1.05-$0.71)	Epoxy (7-9, $0.24-$0.19) Polyurea (7-9, $0.36-$0.29) Urethane (5-6, $0.44-$0.37)	Epoxy (3-4, $0.53-$0.40) Polyurea (3-4, $0.80-$0.61) Urethane (2-3, $1.05-$0.71)	Epoxy (7-9, $0.24-$0.19, $0.36-$0.29) Polyurea (7-9, $0.36-$0.29, $0.48-$0.39) Urethane (5-6, $0.44-$0.37, $0.60-$0.51)
Central IL	Low (≤ 7000)	Epoxy (4-5, $0.40-$0.33) Urethane (3-4, $0.71-$0.54)	Epoxy (8-10, $0.21-$0.18) Polyurea (7-9, $0.36-$0.29)	Epoxy (4-5, $0.40-$0.33) Urethane (3-4, $0.71-$0.54)	Epoxy (8-10, $0.21-$0.18, $0.32-$0.26) Polyurea (7-9, $0.36-$0.29, $0.48-$0.39)
	High (> 7000)	Epoxy (4-5, $0.40-$0.33) Urethane (3-4, $0.71-$0.54) Polyurea (3-4, $0.80-$0.61)	Epoxy (8-10, $0.21-$0.18) Polyurea (7-9, $0.36-$0.29) Urethane (6-7, $0.37-$0.32)	Epoxy (4-5, $0.40-$0.33) Urethane (3-4, $0.71-$0.54) Polyurea (3-4, $0.80-$0.61)	Epoxy (8-10, $0.21-$0.18, $0.32-$0.26) Polyurea (7-9, $0.36-$0.29, $0.48-$0.39) Urethane (6-7, $0.37-$0.32, $0.51-$0.44)
Southern IL	Low (≤ 7000)	Epoxy (4-5, $0.40-$0.33) Urethane (4-5, $0.54-$0.44)	Epoxy (8-10, $0.21-$0.18) Polyurea (8-10, $0.32-$0.26)	Epoxy (4-5, $0.40-$0.33) Urethane (4-5, $0.54-$0.44)	Epoxy (8-10, $0.21-$0.18, $0.32-$0.26) Polyurea (8-10, $0.32-$0.26, $0.43-$0.35)
	High (> 7000)	Epoxy (4-5, $0.40-$0.33) Urethane (4-5, $0.54-$0.44) Polyurea (4-5, $0.61-$0.49)	Epoxy (8-10, $0.21-$0.18) Polyurea (8-10, $0.32-$0.26) Urethane (6-8, $0.37-$0.28)	Epoxy (4-5, $0.40-$0.33) Urethane (4-5, $0.54-$0.44) Polyurea (4-5, $0.61-$0.49)	Epoxy (8-10, $0.21-$0.18, $0.32-$0.26) Polyurea (8-10, $0.32-$0.26, $0.43-$0.35) Urethane (6-8, $0.37-$0.28, $0.51-$0.39)

Recommendations shown are:

Material Type (expected service life, equivalent uniform annual cost per foot for a 4-inch-wide marking)
Costs are based on 2013 average unit prices and a 3% discount rate.

Notes:

1. Costs shown are for placing materials in existing grooves.
   Do not install new grooves for maintenance striping on PCC with less than 10 years remaining service life.
2. First cost shown is for placing materials in existing grooves.
   Second cost shown includes the annualized cost of installing new grooves.

Table 4. Pavement marking material recommendations for striping on new HMA.

STRIPING ON NEW HMA			
Zone	AADT	Surface [1]	Recessed [2]
Northern IL	Low (≤ 7000)	Thermoplastic (3-4, $0.35-$0.27) Paint (1.5-2, $0.52-$0.39)	Thermoplastic (6-7, $0.32-$0.28) Epoxy (6-8, $0.42-$0.32)
Northern IL	High (> 7000)	Thermoplastic (3-4, $0.35-$0.27) Epoxy (2-3, $0.78-$0.53) Polyurea (3-4, $0.80-$0.61) Preformed Plastic, Type B (3-4, $0.97-$0.74) Urethane (2-3, $1.05-$0.71)	Thermoplastic (6-7, $0.32-$0.28) Epoxy (6-8, $0.42-$0.32) Polyurea (7-9, $0.48-$0.39) Preformed Plastic, Type B (7-9, $0.56-$0.45) Urethane (5-6, $0.60-$0.51)
Central IL	Low (≤ 7000)	Thermoplastic (4-5, $0.27-$0.22) Paint (1.5-2, $0.52-$0.39)	Thermoplastic (6-8, $0.32-$0.25) Epoxy (7-9, $0.36-$0.29)
Central IL	High (> 7000)	Thermoplastic (3-4, $0.35-$0.27) Epoxy (3-4, $0.53-$0.40) Preformed Plastic, Type B (4-5, $0.74-$0.60) Polyurea (3-4, $0.80-$0.61) Urethane (2-3, $1.05-$0.71)	Thermoplastic (6-7, $0.32-$0.28) Epoxy (7-9, $0.36-$0.29) Polyurea (7-9, $0.48-$0.39) Preformed Plastic, Type B (8-10, $0.50-$0.41) Urethane (5-6, $0.60-$0.51)
Southern IL	Low (≤ 7000)	Thermoplastic (5-6, $0.22-$0.18) Paint (1-2, $0.77-$0.39)	Thermoplastic (7-9, $0.28-$0.22) Epoxy (7-9, $0.36-$0.29)
Southern IL	High (> 7000)	Thermoplastic (4-5, $0.27-$0.22) Epoxy (3-4, $0.53-$0.40) Polyurea (4-5, $0.61-$0.49) Paint (1-2, $0.77-$0.39) Preformed Plastic, Type B (5-6, $0.60-$0.51) Urethane (3-4, $0.71-$0.54)	Thermoplastic (6-8, $0.32-$0.25) Epoxy (7-9, $0.36-$0.29) Polyurea (7-9, $0.48-$0.39) Preformed Plastic, Type B (8-10, $0.50-$0.41) Urethane (5-6, $0.60-$0.51)

Recommendations shown are:

Material Type (expected service life, equivalent uniform annual cost per foot for a 4-inch-wide marking and a 5-inch-wide groove)
Costs are based on 2013 average unit prices and a 3% discount rate.

Notes:
1 Surface applied preformed plastic shall be inlaid application.
2 Recessed preformed plastic shall be standard application.

Table 5. Pavement marking material recommendations for striping on new PCC.

STRIPING ON NEW PCC			
Zone	AADT	Surface	Recessed
Northern IL	Low (≤ 7000)	Epoxy (3-4, $0.53-$0.40) Polyurea (3-4, $0.80-$0.61) Preformed Plastic, Type B (3-4, $0.97-$0.74) Urethane (2-3, $1.05-$0.71)	Epoxy (7-9, $0.36-$0.29) Polyurea (7-9, $0.48-$0.39)
	High (> 7000)	No Surface Application!	Epoxy (7-9, $0.36-$0.29) Polyurea (7-9, $0.48-$0.39) Preformed Plastic, Type B (7-9, $0.56-$0.45) Urethane (5-6, $0.60-$0.51)
Central IL	Low (≤ 7000)	Epoxy (4-5, $0.40-$0.33) Preformed Plastic, Type B (4-5, $0.74-$0.60) Polyurea (3-4, $0.80-$0.61) Urethane (2-3, $1.05-$0.71)	Epoxy (7-9, $0.36-$0.29) Polyurea (7-9, $0.48-$0.39)
	High (> 7000)	No Surface Application!	Epoxy (7-9, $0.36-$0.29) Polyurea (7-9, $0.48-$0.39) Preformed Plastic, Type B (8-10, $0.50-$0.41) Urethane (5-6, $0.60-$0.51)
Southern IL	Low (≤ 7000)	Epoxy (4-5, $0.40-$0.33) Polyurea (4-5, $0.61-$0.49)	Epoxy (7-9, $0.36-$0.29) Polyurea (7-9, $0.48-$0.39)
	High (> 7000)	Epoxy (4-5, $0.40-$0.33) Polyurea (4-5, $0.61-$0.49) Preformed Plastic, Type B (5-6, $0.60-$0.51) Urethane (3-4, $0.71-$0.54)	Epoxy (7-9, $0.36-$0.29) Polyurea (7-9, $0.48-$0.39) Preformed Plastic, Type B (8-10, $0.50-$0.41) Urethane (5-6, $0.60-$0.51)

Recommendations shown are:

Material Type (expected service life, equivalent uniform annual cost per foot for a 4-inch-wide marking and a 5-inch-wide groove)
Costs are based on 2013 average unit prices and a 3% discount rate.

SECTION 3 INSTALLATION INSPECTION

For markings to reach their expected service lives, they must be installed properly. Major factors that can affect the proper installation of pavement markings are:

- Ambient temperature
- Pavement temperature
- Material temperature
- Pavement surface moisture
- Pavement surface condition (unclean or deteriorated)
- Wind velocity
- Material application rate
- Reflective media application rate

Ambient and pavement temperatures are important because most pavement marking materials require a minimum temperature to achieve proper drying or curing. Material temperature must remain constant so that the material's viscosity remains constant. If the viscosity changes, then the material application rate can be affected and, of greater consequence, the mix ratio of plural component pavement markings (epoxy, polyurea, and modified urethane) will be altered. Pavement surface moisture at the time of application can prevent the marking material from sufficiently bonding with the pavement surface. Wind velocity can affect the application of drop-on reflective media. High winds can cause the reflective media to be poorly dispersed or from reaching the binder material altogether. Material applied too thin will not provide a sufficient substrate for the reflective media to bind to, and beads may sink in material applied too thickly.

The exhibit that accompanies this guide contains installation inspection sheets for materials currently approved for long line pavement markings and an inspection sheet for installing a groove for recessed markings. Criteria listed in these check sheets comply with IDOT Standard Specifications for Road and Bridge Construction.

The following sections describe recommended tests and measurement tools for several of the inspection items.

3.1 Groove Depth Measurement

To assess whether a groove depth is within the allowable range, an inspector will need two plates that are narrower than the groove width and a straight edge that is wider than the groove width. One plate should be the thickness of the minimum allowable groove depth, and the other plate should be the thickness of the maximum allowable depth. The measurement steps are:

1. Place the thinner plate in the groove and lay a straight edge over the plate.
    - If the straight edge rests on the plate and doesn't touch the pavement, then the groove is too shallow.
    - If the straight edge rests on both the plate and the pavement, or on just the pavement, then the groove depth meets the minimum allowable depth.

2. Place the thicker plate in the groove and lay a straight edge over the plate.
    - If the straight edge rests on the pavement and there is a gap between the plate and the straight edge, then the groove is too deep.
    - If the straight edge rests on the plate and the pavement, or on just the plate, then the groove depth does not exceed the maximum allowable depth.

Grooves for preformed plastic are to be cut with gang-stacked diamond saw blades. Ridges within the groove are not to exceed 15 mils in height. Ridge heights may be measured with a contour gauge. If ridge heights exceed 15 mils, then the saw blades may need to be replaced.

3.2 Pavement Surface Cleaning

The surface wetting test is a method for determining whether the pavement surface has been sufficiently cleaned to place pavement markings. Using an eye dropper, place a drop of clean drinking water on the pavement surface. If the drop forms a bead, the surface may need to be re-cleaned. If the drop spreads (wets), the surface is ready to accept application of marking.

3.3 Pavement Surface Moisture

The surface moisture test is a method for determining whether the pavement is dry enough to accept application of marking material. The test steps are:

1. Place a 12" x 12" piece of plastic wrap on the pavement surface and tape the edges.
2. Leave the plastic wrap in place for approximately 15 minutes.
3. After 15 minutes, check for moisture bubbles on the inside surface of the plastic.
4. If moisture bubbles are larger than a pencil eraser, then the pavement has too much water.

3.4 Material Thickness

Markings with a required wet film thickness of 80 mils or less should be measured with a wet film thickness gauge. Figure 2 is an example of a wet film thickness gauge. To measure wet film thickness, press the edge of the gauge vertically into the wet material. Withdraw the gauge and note the deepest tooth with material on it and the next higher tooth that is not coated with material. The wet film thickness lies between these two readings. For materials thicker than 80 mils, place a metal plate or duct tape down in advance of the striping operation. Collect the sample after striping, and when the material has cooled, remove pieces of the sample and measure the thickness with a needle-point micrometer.

Figure 2. Wet film thickness gauge.

3.5 Glass Bead Application Rate

Most glass bead application rates are given in pounds of beads per gallon of the specified marking material. To ensure that beads are applied at the specified rate, the bead guns must be calibrated prior to marking installation. Verifying that the calibration is performed is an inspector's best opportunity to ensure that rates will be met. To calibrate bead guns, the desired travel speed must first be known. Then, while the striping truck is stationary, beads are sprayed into a container for a pre-determined amount of time, usually a few seconds. Figure 3 is a photo of this step.

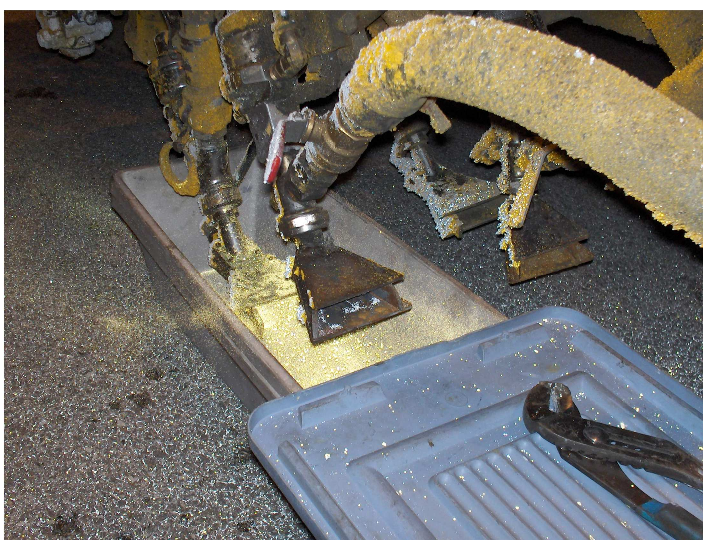


Figure 3. Glass bead calibration.

The beads are then poured into a graduated cylinder, and the volume of beads is read. The volume of beads should correspond with the required application rate for a given travel speed. For example, to place 10 pounds of Type I glass beads per gallon of material while traveling 4 miles per hour, the volume of beads collected during a 15-second spray should be 1,200 milliliters. If the volume is too low, then the bead flow needs to be increased. If the volume is too high, then the bead flow needs to be decreased. Table 6 is a bead gun calibration chart for a 10-second spray of Type I beads being placed on a 6-inch-wide marking with a 15-mil wet film thickness. Bead calibration charts for other bead types and other marking material widths and thicknesses may be acquired from material manufacturers.

Table 6. Volume (milliliters) of Type I glass beads using a 10-second spray for a 6-inch-wide marking with a 15-mil wet film thickness

Travel Speed (MPH)	Bead Application Rates			
	6 lbs/gal	8 lbs/gal	10 lbs/gal	12 lbs/gal
8	960	1280	1600	1920
7	840	1120	1400	1680
6	720	960	1200	1440
5	600	800	1000	1200
4	480	640	800	960
3	360	480	600	720
2	240	320	400	480

3.6 Glass Bead Dispersion/Retroreflectivity

At the time of this guide's publication, IDOT specifications did not require a minimum retroreflectivity, but markings are required to be retroreflective. Therefore, the "Sun Over Shoulder" test, from Texas DOT Test Method Tex-828-B, can be used to assess retroreflective properties. The test steps are:

1. When the sun is between 20 and 80 degrees above the horizon, position yourself so that the sun is behind you.
2. View the stripe in front of you along a plane parallel to your shadow.
3. Adjust your distance from the stripe to where the shadow of your head touches the stripe area being observed.
4. From this position, evaluate bead dispersion and retroreflective qualities of the stripe.

Figure 4 shows a demonstration of this test method.

Figure 4. Demonstration of sun over shoulder test method.

Glass beads will provide optimum retroreflectivity if they are properly embedded in the liquid marking material. To achieve optimum retroreflectivity, 50% to 60% of the bead diameter should be below the surface of the marking material. A magnifying lens can be used to examine the depth of bead embedment.

Exhibit

Installation Inspection Sheets

Grooving for Recessed Markings

Contract No:		**Location**			
Pay Item No:		Route			
Date:		Beg MP/Sta:	End MP/Sta:		
Inspector:		**Lines (Circle All That Apply)**			
Site Notes:		L Edge	Lane Line: 1 2 3	R Edge	
		Note: Lane lines are counted left to right from the direction of travel			
		Symbols Present?	Yes	No	

I. TEST SECTION

1. Groove Depth

Minimum Allowable Groove Depth (mils) =		Maximum Allowable Groove Depth (mils) =	

At the start of grooving operations, Contractor shall install a 50 ft test section.
Groove depth measurements shall be taken at 10 ft intervals within the test section.
All groove depth measurements shall be within allowable range.

	Groove Depth Measurements				
	#1	#2	#3	#4	#5
Is measurement within allowable range? (yes/no)					

Are all 5 measurements within the allowable range? (yes/no)	

2. Surface Texture

A. For Preformed Plastic Pavement Marking Installations

Is groove surface smooth, and are any ridges less than 16 mils in height? (yes/no)	

B. For Liquid Pavement Marking Installations

Does groove have a regular textured surface? (yes/no)	

3. Groove Width

Is groove width one inch wider than the specified pavement marking line? (yes/no)	

II. GROOVE INSTALLATION

1. Distance from Longitudinal Joint of Edge

Required Distance:	≥ 4"	Measured Distance =	

2. Depth Consistency

Was cutting head operated at the appropriate speed in order to prevent undulation of the cutting head and grooving at an inconsistent depth? (yes/no)	

III. NOTES

Preformed Plastic - Inlaid Application

Contract No:		**Location**					
Pay Item No:		Route					
Date:		Beg MP/Sta:		End MP/Sta:			
Inspector:		**Lines (Circle All That Apply)**					
Site Notes:		L Edge	Lane Line:	1	2	3	R Edge
		Note: Lane lines are counted left to right from the direction of travel					
		Symbols Present?		Yes		No	

I. SURFACE PREPARATION

1. Surface Cleaning

Is surface free of dirt and debris? (yes/no)	

2. Surface Moisture

Has it rained in the past 24 hours? (yes/no)	
Is the pavement surface dry? (yes/no)	

3. Pavement Temperature

Required Temp:	150°F ± 5°F	Measured Temp =	

II. PAVEMENT MARKING APPLICATION

1. Ambient Temperature

Measured Temp =	

2. Tamping

Was tape tamped with a 200lb load? (yes/no)	

* Note: Approximately 2/3 of the thickness of the tape should be embedded in the HMA.

3. Distance from Longitudinal Joint or Pavement Edge

Required Distance:	≥ 2"	Measured Distance =	

4. Lateral Deviation

Does the lateral deviation of any 10 ft section exceed 1 inch? (yes/no)	

III. NOTES

Preformed Plastic - Standard Application

Contract No:		**Location**					
Pay Item No:		Route					
Date:		Beg MP/Sta:		End MP/Sta:			
Inspector:		**Lines (Circle All That Apply)**					
Site Notes:		L Edge	Lane Line:	1	2	3	R Edge
		Note: Lane lines are counted left to right from the direction of travel					
		Symbols Present?		Yes		No	

I. SURFACE PREPARATION

1. Surface Age			
What is the pavement's surface age?			
Notes:	All standard applied preformed plastic shall be recessed.		
	New PCC Pavement:	Surface cleaning (and marking placement) shall not begin until 30 days or more of curing.	
	New HMA & Seal Coat Surfaces:	Surface cleaning (and marking placement) shall not begin until 2 weeks after placement of pavement surface.	
2. Surface Cleaning			
Was surface cleaned to remove dirt, grease, and debris? (yes/no)			
New Textured Surface PCC:	Has all visible evidence of curing compounds on peaks and valleys been removed? (yes/no)		
3. Surface Moisture			
Has it rained in the past 24 hours? (yes/no)			
Is the pavement surface dry? (yes/no)			
4. Pavement Temperature			
Required Temp:	≥ 70°F	Measured Temp =	

II. PAVEMENT MARKING APPLICATION

1. Ambient Temperature			
Required Temp:	≥ 60°F	Measured Temp =	
2. Primer Sealer			
Is a primer sealer required? (yes/no)		If yes, was it placed? (yes/no)	
3. Tamping			
Was tape tamped with a 200lb load? (yes/no)			
4. Distance from Longitudinal Joint or Pavement Edge			
Required Distance:	≥ 2"	Measured Distance =	
5. Lateral Deviation			
Does the lateral deviation of any 10 ft section exceed 1 inch? (yes/no)			

Paint

Contract No:		**Location**	
Pay Item No:		Route	
Date:		Beg MP/Sta:	End MP/Sta:
Inspector:		**Lines (Circle All That Apply)**	
Site Notes:		L Edge | Lane Line: 1 2 3 | R Edge	
		Note: Lane lines are counted left to right from the direction of travel	
		Symbols Present?	Yes No

I. SURFACE PREPARATION

1. Surface Cleaning	
Was surface cleaned to remove dirt, grease, and debris? (yes/no)	
2. Surface Moisture	
Has it rained in the past 24 hours? (yes/no)	
Is the pavement surface dry? (yes/no)	

II. PAVEMENT MARKING APPLICATION

1. Ambient Temperature			
Required Temp:	≥ 50°F	Measured Temp =	
2. Wet Film Thickness			
Required Thickness:	≥ 16 mils	Measured Thickness =	
3. Glass Bead Application Rate			
Required Rate =	6.0 lb/gal	Measured Rate =	
4. Bead Dispersion / Retroreflectivity			
Are beads well dispersed? (yes/no)			
Is marking retroreflective? (yes/no)			
5. Distance from Longitudinal Joint or Pavement Edge			
Required Distance:	≥ 2"	Measured Distance =	
6. Lateral Deviation			
Does the lateral deviation of any 10 ft section exceed 1 inch? (yes/no)			
7. Marking Width			
Required Width =	Specified Width ± 1/4"	Measured Width =	

III. NOTES

Thermoplastic

Contract No:		**Location**					
Pay Item No:		Route					
Date:		Beg MP/Sta:			End MP/Sta:		
Inspector:		**Lines (Circle All That Apply)**					
Site Notes:		L Edge	Lane Line:	1	2	3	R Edge
		Note: Lane lines are counted left to right from the direction of travel					
		Symbols Present?		Yes		No	

I. SURFACE PREPARATION			
1. Surface Cleaning			
Was surface cleaned to remove dirt, grease, and debris? (yes/no)			
2. Surface Moisture			
Has it rained in the past 24 hours? (yes/no)			
Is the pavement surface dry? (yes/no)			
3. Pavement Temperature			
Required Temp:	≥ 55°F	Measured Temp =	
II. PAVEMENT MARKING APPLICATION			
1. Resin Temperature			
Required Temp =	400 - 475°F	Measured Temp =	
2. Applied Material Thickness			
Required Thickness =	100 - 110 mils	Measured Thickness =	
3. Glass Bead Application Rate			
Required Rate =		Measured Rate =	
4. Bead Dispersion / Retroreflectivity			
Are beads well dispersed? (yes/no)			
Is marking retroreflective? (yes/no)			
5. Distance from Longitudinal Joint or Pavement Edge			
Required Distance:	≥ 2"	Measured Distance =	
6. Lateral Deviation			
Does the lateral deviation of any 10 ft section exceed 1 inch? (yes/no)			
7. Marking Width			
Required Width =	Specified Width ± 1/4"	Measured Width =	
III. NOTES			

Epoxy

Contract No:		**Location**			
Pay Item No:		Route			
Date:		Beg MP/Sta:		End MP/Sta:	
Inspector:		**Lines (Circle All That Apply)**			
Site Notes:		L Edge	Lane Line: 1 2 3		R Edge
		Note: Lane lines are counted left to right from the direction of travel			
		Symbols Present?	Yes	No	

I. SURFACE PREPARATION

1. Surface Cleaning			
New PCC Pavement:	Was surface air-blasted clean to remove all curing compounds and latents? (yes/no)		
All Other Pavements:	Was surface cleaned to remove dirt, grease, and debris? (yes/no)		
2. Surface Moisture			
Has it rained in the past 24 hours? (yes/no)		Is the pavement surface dry? (yes/no)	
3. Pavement Temperature			
Required Temp:	≥ 35°F	Measured Temp =	

II. PAVEMENT MARKING APPLICATION

1. Ambient Temperature			
Required Temp:	≥ 35°F	Measured Temp =	
2. Material Temperatures			
Temp Prior to Mixing =		Temp at Gun Tip =	
3. Wet Film Thickness			
Required Thickness =	20 mils ± 1 mil	Measured Thickness =	
4. Small Glass Bead Application Rate			
Required Rate =	10 lb/gal	Measured Rate =	
5. Large Glass Bead Application Rate			
Required Rate =	10 lb/gal	Measured Rate =	
6. Bead Dispersion / Retroreflectivity			
Are beads well dispersed? (yes/no)		Is marking retroreflective? (yes/no)	
7. Distance from Longitudinal Joint or Pavement Edge			
Required Distance:	≥ 2"	Measured Distance =	
8. Lateral Deviation			
Does the lateral deviation of any 10 ft section exceed 1 inch? (yes/no)			
9. Marking Width			
Required Width =	Specified Width ± 1/4"	Measured Width =	

Modified Urethane

Contract No:		**Location**	
Pay Item No:		Route	
Date:		Beg MP/Sta:	End MP/Sta:
Inspector:		**Lines (Circle All That Apply)**	
Site Notes:		L Edge / Lane Line: 1 2 3 / R Edge	
		Note: Lane lines are counted left to right from the direction of travel	
		Symbols Present?	Yes No

I. SURFACE PREPARATION

1. Surface Cleaning			
New PCC Pavement:	Was surface air-blasted clean to remove all curing compounds and latents? (yes/no)		
All Other Pavements:	Was surface cleaned to remove dirt, grease, and debris? (yes/no)		
2. Surface Moisture			
Has it rained in the past 24 hours? (yes/no)		Is the pavement surface dry? (yes/no)	
3. Pavement Temperature			
Required Temp:	≥ 35°F	Measured Temp =	

II. PAVEMENT MARKING APPLICATION

1. Ambient Temperature			
Required Temp:	≥ 35°F	Measured Temp =	
2. Material Temperatures			
Temp Prior to Mixing =		Temp at Gun Tip =	
3. Wet Film Thickness			
Required Thickness =	20 mils ± 1 mil	Measured Thickness =	
4. Small Glass Bead Application Rate			
Required Rate = (Manufacturer's Rate)		Measured Rate =	
5. Large Glass Bead Application Rate			
Required Rate = (Manufacturer's Rate)		Measured Rate =	
6. Bead Dispersion / Retroreflectivity			
Are beads well dispersed? (yes/no)		Is marking retroreflective? (yes/no)	
7. Distance from Longitudinal Joint or Pavement Edge			
Required Distance:	≥ 2"	Measured Distance =	
8. Lateral Deviation			
Does the lateral deviation of any 10 ft section exceed 1 inch? (yes/no)			
9. Marking Width			
Required Width =	Specified Width ± 1/4"	Measured Width =	

Polyurea

Contract No:		**Location**	
Pay Item No:		Route	
Date:		Beg MP/Sta:	End MP/Sta:
Inspector:		**Lines (Circle All That Apply)**	
Site Notes:		L Edge	Lane Line: 1 2 3 R Edge
		Note: Lane lines are counted left to right from the direction of travel	
		Symbols Present?	Yes No

I. SURFACE PREPARATION			
1. Surface Cleaning			
New PCC Pavement:	Was surface air-blasted clean to remove all curing compounds and latents? (yes/no)		
All Other Pavements:	Was surface cleaned to remove dirt, grease, and debris? (yes/no)		
2. Surface Moisture			
Has it rained in the past 24 hours? (yes/no)		Is the pavement surface dry? (yes/no)	
3. Pavement Temperature			
Required Temp:	≥ 40°F	Measured Temp =	
II. PAVEMENT MARKING APPLICATION			
1. Ambient Temperature			
Required Temp:	≥ 40°F	Measured Temp =	
2. Material Temperatures			
Temp Prior to Mixing =		Temp at Gun Tip =	
3. Wet Film Thickness			
Required for new HMA: Required for other pavements:	≥ 20 mils ≥ 15 mils	Measured Thickness =	
4. Small Glass Bead Application Rate			
Required Rate = (Manufacturer's Rate)		Measured Rate =	
5. Large Glass Bead Application Rate			
Required Rate = (Manufacturer's Rate)		Measured Rate =	
6. Bead Dispersion / Retroreflectivity			
Are beads well dispersed? (yes/no)		Is marking retroreflective? (yes/no)	
7. Distance from Longitudinal Joint or Pavement Edge			
Required Distance:	≥ 2"	Measured Distance =	
8. Lateral Deviation			
Does the lateral deviation of any 10 ft section exceed 1 inch? (yes/no)			
9. Marking Width			
Required Width =	Specified Width ± 1/4"	Measured Width =	

SECTION 4 SUPPORTING DOCUMENTS

Documents related to or supporting this guide are the FHWA's Manual on Uniform Traffic Code Devices (MUTCD), IDOT's Standard Specifications for Road and Bridge Construction, and Illinois Center for Transportation (ICT) research project R27-77, "Evaluating Pavement Markings on Portland Cement Concrete and Various Asphalt Surfaces." Copies of these documents can be found at the following links:

MUTCD
http://mutcd.fhwa.dot.gov/

IDOT Standard Specifications for Road and Bridge Construction
http://www.dot.il.gov/desenv/hwyspecs.html

ICT Project R27-77
http://www.ict.illinois.edu: (click on the "Research" tab at the top of the page, then from the drop-down menu, select "Publications" and search for project R27-77).