



EVALUATION OF CEMENT-BASED PAVEMENT MARKINGS: CONDUCT OF RESEARCH REPORT

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September 2026

Research Project
Reporting on VTRC025 602

Final Report 2026-06

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Technical Report Documentation Page

1. Report No. 2026-06	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Evaluation of Cement-Based Pavement Markings: Conduct of Research Report		5. Report Date September 2026	
		6. Performing Organization Code	
7. Author(s) Dwyer, Carmine, ORCID 0000-0003-4501-2358, https://orcid.org/0000-0003-4501-2358		8. Performing Organization Report No.	
9. Performing Organization Name and Address Applied Research Associates, Inc. 100 Trade Centre Drive., Suite 200 Champaign, IL 61820		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. GR1972	
12. Sponsoring Agency Name and Address Vermont Agency of Transportation (SPR) Research Program 2178 Airport Rd Unit B Barre VT 05641		13. Type of Report and Period Covered Final Report 2025-2026	
		14. Sponsoring Agency Code	
15. Supplementary Notes Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration. https://vtrans.vermont.gov/sites/aot/files/Research/Conduct%20of%20Research%20Report_Evaluation%20of%20Cement-Based%20Pavement%20Markings.pdf			
16. Abstract Pavement markings provide continuous safety information to roadway users related to the roadway alignment, vehicle positioning, and other important driving-related tasks. During nighttime hours on many roadways, pavement markings are the only roadway asset to guide and regulate traffic. Therefore, it is important that pavement markings are performing well, are both durable and retroreflective. However, there are many factors that can affect pavement marking performance, such as the environment, traffic, and winter maintenance practices. The Vermont Agency of Transportation (VTrans) experiences significant challenges with all these factors. Additionally, besides the potential safety risks to roadway travelers, there are financial costs to VTrans for frequently replacing markings. However, a relatively new pavement marking material, a polymer modified cement-based pavement marking, has the potential for being more durable than other marking materials. With a longer service life, it also has the potential for having a competitive annualized cost. In Spring 2025 VTrans awarded a research study to Applied Research Associates, Inc. (ARA) to conduct an evaluation of the cement-based marking. The objectives of the study were to perform a measured assessment of the marking's performance on VTrans roadways, determine an estimated service life, and from the service life calculate the material's annualized cost. However, the marking manufacturer, which had offered to install the test markings at no cost, did not follow through on that offer. Therefore, VTrans made the decision to cancel the study. This conduct of research report serves as a record of the work completed before the study's cancellation.			
17. Key Words Pavement markings, cement-based, Enduramark, pavement marking performance, retroreflectivity		18. Distribution Statement No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.	
19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages 29	22. Price \$38,300

Evaluation of Cement-Based Pavement Markings: Conduct of Research Report

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Applied Research Associates, Inc.

Prepared for
Vermont Agency of Transportation

September 2026

Final Report

2026-06

Acknowledgments

The project team would like to thank the VTrans Research Office, the Technical Advisory Committee (TAC) members, and the Project Champion (Philip Peloquin) for their technical assistance and coordination in this project.

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List of Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ADAS	Advanced Driver Assistance Systems
ASTM	American Society for Testing and Materials
GDOT	Georgia Department of Transportation
MDOT	Michigan Department of Transportation
MMA	Methyl Methacrylate
NJDOT	New Jersey Department of Transportation
PEAS	Product Evaluation and Audit Solution
TAC	Technical Advisory Committee
TCP	Traffic Control Plan
UV	Ultraviolet
VTrans	Vermont Agency of Transportation

Executive Summary

Pavement markings provide continuous safety information to roadway users related to the roadway alignment, vehicle positioning, and other important driving-related tasks. During nighttime hours on many roadways, pavement markings are the only roadway asset to guide and regulate traffic, and their visibility becomes even more critical during nighttime wet conditions. Additionally, today pavement markings must be visible not only to human drivers but also to the machine vision technology of Advanced Driver Assistance Systems (ADAS) common in many vehicles

For these reasons, it is important that pavement markings are performing well, are both durable and retroreflective (provide nighttime visibility), to aid with safe roadway navigation. However, there are many factors that can affect pavement marking performance, such as the environment, traffic, and winter maintenance practices. The Vermont Agency of Transportation (VTrans) experiences significant challenges with all these factors. Vermont's climate, which has low winter temperatures and harsh freeze-thaw cycles, places considerable strain on a pavement marking material's capacity to remain bonded to the pavement surface. The repeated freeze-thaw cycles have caused marking materials to crack or peel. The tire abrasion from high traffic volumes, especially heavy truck traffic, accelerates wear on pavement markings, and winter maintenance practices, particularly in northern states like Vermont, significantly impact the longevity and effectiveness of pavement markings. The frequent mechanical abrasion from snowplows accelerates marking degradation, and deicing agents cause chemical degradation such as fading, stripping, and surface damage.

Besides the potential safety risks to roadway travelers, there are other consequences for rapidly deteriorating pavement markings. The financial costs to VTrans for frequently replacing markings can be significant. However, a relatively new pavement marking material, a polymer modified cement-based pavement marking, has the potential for being more durable than other marking materials. With a longer service life, it also has the potential for having a competitive annualized cost. For these reasons, in the spring of 2025, VTrans awarded a research study to Applied Research Associates, Inc. (ARA) to conduct an evaluation of the cement-based marking. The objectives of the study were to perform a measured assessment of the marking's performance on VTrans roadways, determine an estimated service life, and from the service life calculate the material's annualized cost.

The tasks planned for the study were as follows:

1. Kickoff Meeting
2. Literature Review
3. Test Site Selection and Installation
4. Data Collection
5. Data Analysis
6. Life Cycle Cost Analysis
7. Final Report and Technology Transfer

The literature review was completed, and the test site selection was completed. However, the marking manufacturer, which had offered to install the test markings at no cost to VTrans, did not follow through on that offer. The test section was originally to be installed in the fall of 2025, but due to equipment delivery delays the manufacturer could not perform the installation. VTrans then approved postponing the installation until the spring of 2026 with an installation date no later than June 19, 2026. When the marking manufacturer had still not installed the test section by that date, VTrans made the decision to cancel the study. This conduct of research report serves as a record of the work completed before the study's cancellation.

Chapter 1. Introduction

Pavement markings provide continuous safety information to roadway users related to the roadway alignment, vehicle positioning, and other important driving-related tasks. During nighttime hours on many roadways, pavement markings are the only roadway asset to guide and regulate traffic, and their visibility becomes even more critical during nighttime wet conditions. Additionally, today pavement markings must be visible not only to human drivers but also to the machine vision technology of Advanced Driver Assistance Systems (ADAS) common in many vehicles.

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Chapter 2. Literature Review

A draft literature review was submitted to the VTrans Technical Advisory Committee (TAC) in October 2025. After TAC review and revisions, the final literature review was submitted in February 2026. A copy of the final literature review is included in the Appendix. The literature and information that was gathered, reviewed and summarized included the following:

- Three previous VTrans pavement marking research study reports
- VTrans 5-year average bid prices for 4-inch surface-applied pavement markings
- Cement-based marking's product data sheet
- Cement-based marking's safety data sheet
- Phone call and email surveys with the Michigan DOT and Bergen County, NJ about their experiences with the cement-based marking
- Cement-based marking data from the AASHTO Product Evaluation and Audit Solution (PEAS) under DataMine

Three other national and state research studies focused on evaluation of pavement marking service lives and pavement marking selection

Chapter 3. Test Site Selection

In July 2025, the research team began coordinating with the TAC to identify the desired test site features and select the test site location. The desired test site features were as follows:

- Horizontal curve edge line, intended to capture higher snowplow and truck traffic abrasion
- Tangent section edge line
- Centerline rumble stripe
- Skip line
- Stop bars for local roads

A section of US-7 south of Burlington (near the town of Charlotte, VT) was selected as the site for the line markings, and a little south of that site, the intersection of US-7 and Church Hill Rd was selected as the site for the stop bar test markings. The line marking test site and its features are shown in Figure 1, and the stop bar test site is shown in Figure 2. US-7 was selected because it was recently resurfaced, and therefore, we did not expect any pavement deterioration to impact the performance of the test site markings.

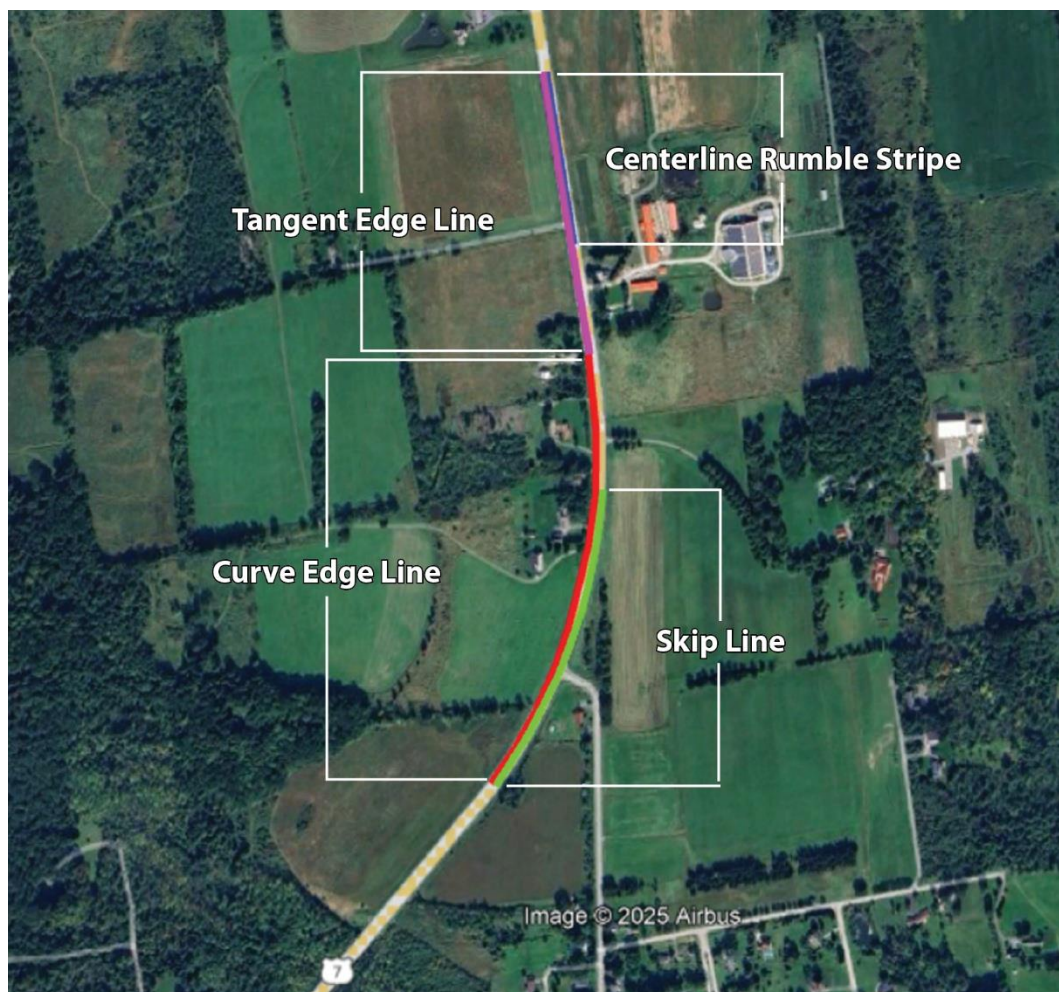


Figure 1. Test site for line markings (US-7 south of Burlington)



Figure 2. Test site for stop bars

The desired test site features and test site location were identified before the end of August 2025 so that the markings could be installed in September. However, a specific paint truck is required to install the cement-based markings, and the manufacturer, who also owns a striping business, only had one of these trucks. The one truck was being used on other projects, but a second truck was expected. The delivery of the second truck was over two months behind schedule. The marking manufacturer reviewed and agreed to the test site location, features, and marking quantities, but as the end of the striping season approached and temperatures were too cold to place markings, the second truck had still not been delivered. The research team and the TAC agreed that the installation had to be moved to the spring. Unfortunately, with the loss of the Fall 2025 installation, the study was going to lose one full winter's evaluation of the marking's performance. The manufacturer agreed to place the markings in May 2026.

ARA had subcontracted with ADA Traffic Control to provide traffic control during each round of the test site's data collection of marking performance metrics. A formal Traffic Control Plan (TCP) was developed by ADA, and after a few rounds of review by VTrans and revision by ADA, the TCP was approved.

The research team was fully prepared for the test site installation and to perform the planned rounds of marking performance data collection. The testing planned was as follows:

1. Durability
2. Dry retroreflectivity (ASTM E1710)
3. Wet recovery retroreflectivity (ASTM E2177)
4. Continuous wetting retroreflectivity (ASTM E2832)

Figure 3 is a photo of the LTL-3500 handheld retroreflectometer that was planned for collecting the pavement marking retroreflectivity data.



Figure 3. Handheld retroreflectometer planned for performance testing

However, May 2026 passed and the manufacturer had still not installed the test site. The TAC and research team agreed that a deadline needed to be given to the manufacturer. June 19, 2026 was selected as the deadline. The manufacturer once again agreed but never made the test site installation a priority. The test site was not installed by June 19th. The manufacturer never offered any further options, and without any reasonable alternatives, the TAC made the decision to cancel the study.

Chapter 4. Summary

The literature review summarized the known information about the performance of the cement-based marking in Michigan, New Jersey, and the AASHTO PEAS test deck. Reportedly the marking has recently been installed in Texas and California, but the climates from those two states are not comparable to the winter weather and snow removal that Vermont experiences. Without any further information or results from direct performance measurement on VTrans roadways, no recommendation can be made on the use of cement-based markings in Vermont.

Appendix A: Literature Review

Common Pavement Marking Materials

A variety of pavement marking materials are used across the United States, and their performance varies significantly depending on binder chemistry, pavement surface condition, traffic level, and environmental exposure. In northern climates such as Vermont, the combination of freeze-thaw cycles, snowplowing, and deicing chemicals substantially shortens service life by accelerating bead loss, binder degradation, and adhesion failure.

The Vermont Agency of Transportation (VTrans) classifies retroreflective pavement markings into four primary categories: Paint Pavement Markings, Durable Pavement Markings, Temporary Pavement Markings, and Other Related Markings. Durable markings are further subdivided into liquid-applied systems and preformed tapes. The following subsections focus on the major categories of permanent pavement marking materials and compare their application requirements and performance characteristics based on findings from the available literature [3, 5, 10, 12, 13].

Waterborne Paints

Waterborne paints are the most widely used pavement marking materials in the United States due to their low initial cost, environmental compliance, and ease of application. The paints are typically acrylic latex formulations applied at 15-20 mils thickness and can be applied quickly with minimal disruption to traffic.

However, proper environmental conditions are critical for successful application. Both air and pavement surface temperatures should be at least 50°F and rising, with relative humidity below 50% and adequate air movement (greater than 6 mph). The paint must not be heated above 104°F before application, and surfaces should be dry and above the dew point. For spray applications, a minimum temperature of 55°F may be recommended, though low-temperature formulations exist for use below 50°F.

The durability of the markings in cold climates is limited to less than one year, many times requiring restriping twice a year. It is also observed that the retroreflectivity of the marking material decreases rapidly, particularly under wet-night conditions when water films cover the glass beads. Therefore, waterborne paint markings remain as a low-cost, short-term solution.

Thermoplastic Markings

Thermoplastic markings are among the most common durable pavement markings. They are hot-applied resins with pigments, fillers, and beads, typically placed at 60-120 mils thickness. The material hardens rapidly, typically within 5 minutes, making them suitable for high-traffic installations. They are generally preferred for asphalt surfaces, as the material forms a thermal bond with the pavement through heat fusion. However, installation requires pavement and ambient temperatures of at least 50°F, and the material must be heated to 400-450°F during application. Further, reapplication over existing markings usually requires surface grinding or milling to achieve proper bonding.

When newly installed, thermoplastic markings offer good retroreflectivity and color stability. However, in cold climates, they are prone to cracking and debonding due to their stiffness and thermal mismatch with asphalt. Snowplowing and freeze-thaw cycles often cause edge chipping and bead loss, leading to faster performance degradation. In these environments, the typical service life ranges from 2 to 4 years.

Epoxy Markings

Epoxy markings are two-component thermoset systems that cure through a chemical reaction upon mixing. They bond well to both asphalt and concrete pavements and exhibit good resistance to fuel and chemical exposure. Epoxy markings perform well on high-volume routes but are susceptible to yellowing and brittleness over time under prolonged UV exposure and repeated freeze-thaw cycles. In addition, snowplowing contributes to surface chipping and bead loss. Epoxy markings must be applied when both air and pavement temperatures are 35°F or higher, with an ideal temperature range being between 70°F and 80°F for optimal curing. Further, a minimum dry film thickness of 20 mils is recommended, and dry surface conditions are required. Service life in Vermont commonly ranges from 2 to 3 years.

Polyurea Markings

Polyurea markings are fast-curing, high-performance coatings valued for their flexibility, strong bead retention, and resistance to UV degradation. These materials are suitable for cold-weather installations, with applications possible at air and pavement temperatures as low as 30°F. The target start-up component temperature is 120°F. They cure rapidly, typically within 10 minutes, minimizing traffic disruption. However, application over dew, frost or other visible moisture is not recommended. The application thicknesses range from 15 to 26 mils, depending on surface texture, bead rate, and desired retroreflectivity.

In Vermont, polyurea markings have shown good durability under snowplowing when properly bonded with service lives of approximately 3 to 4 years on interstates and high-volume roadways. However, they are highly sensitive to application parameters such as surface moisture, temperature, and mix ratio. The high material and equipment costs may limit their use to high-priority corridors or safety-critical projects where the longer service life justifies investment.

Methyl Methacrylate (MMA) Markings

Methyl Methacrylate (MMA) pavement markings are cold-applied, two-component systems that polymerize using a peroxide initiator. They provide good color stability, skid resistance, and resistance to chemical and mechanical wear. When properly applied, MMA can achieve a service life of 5 to 8 years, even in moderate to cold climates.

MMA should be applied when air temperature is over 40°F and surface temperatures are between 35°F and 105°F. Relative humidity should be below 75%, and the pavement must be clean, dry, and free of contaminants. Even small amounts of surface moisture or variation in catalyst ratios can result in poor bonding or soft, under-cured areas. On newly paved asphalt, the presence of flux oils can inhibit bonding and cause discoloration. To mitigate this, the surface should be exposed to traffic for 4 to 8 weeks prior to pavement marking application. Other disadvantages include strong odor during installation, need for trained personnel and close control of material proportioning, mixing, and surface

preparation. These factors make MMA installation more difficult than most other materials. For this reason, MMA is often used for intersections, crosswalks, and symbols rather than for long-line markings.

Preformed Tapes

Preformed retroreflective tapes generally provide the highest initial retroreflectivity and longest service life among all existing pavement markings. When inlaid or recessed, tapes can last 5 to 8 years in cold regions, maintaining retroreflectivity above 300-400 mcd/m²/lux. However, surface-applied tapes are less durable and prone to edge lifting.

Although preformed tapes have a higher initial cost compared to other marking types, they are often associated with the lowest life-cycle cost. This is primarily due to their extended performance life and minimal maintenance requirements.

Table 1 provides a summary of average price, dry time, and estimated service life for the pavement marking materials discussed, for quick reference.

Table 1. Pavement Marking Material Comparison Table.

Marking Material	Average Price (per LF)	Dry Time ⁵	Estimated Service Life ⁵
Waterborne Paint	\$0.08 ¹	5 – 10 min	6 – 12 months
Thermoplastic	\$3.67 ^{1,3}	< 5 min	2 – 4 years
Epoxy Paint	\$0.90 ¹	20 – 90 min	2 – 3 years ⁴
Polyurea	\$2.81 ¹	5 – 10 min	3 – 4 years ⁴
MMA	\$4.50 ²	20 – 60 min	5 – 8 years
Recessed Type A Tape	\$9.09 ¹	Immediate	5 – 8 years

Note:

1. The average prices are based on VTrans 5-year average bid prices for 4-inch white line ^[11]. All costs represent surface-applied markings unless otherwise noted.
2. The cost for MMA is based on TxDOT Pavement Marking Handbook ^[9] and adjusted for inflation.
3. Thermoplastic markings typically cost around \$0.20 per linear foot; however, the higher unit costs observed in Vermont may be attributed to limited availability of installation equipment, as noted in the VTrans liquid pavement markings comparison study ^[13].
4. Typical service lives observed in Vermont.
5. Dry times and service life vary significantly by environmental conditions, traffic wear, and winter maintenance practices.

Pavement Marking Research in Vermont

As part of its ongoing commitment to identifying durable pavement marking solutions suitable for Vermont's climate, the Vermont Agency of Transportation has undertaken multiple field research studies dating back to 2002. Two of the most recent and relevant evaluations are reviewed below.

Pavement Marking Comparison Study - I-89 Liquid Markings ^[13]

A multi-year field study was concluded in 2018 to evaluate the performance of five liquid pavement marking materials - Waterborne, MMA, Polyurea, Thermoplastic, and Epoxy - installed along a 15-mile

stretch of I-89 between Brookfield and Montpelier. The goal of this experimental project was to assess retroreflectivity performance and material durability under Vermont's challenging environmental and winter maintenance conditions.

Each material type was represented by a single manufacturer's product and was applied using both recessed and surface-applied methods, with approximately 1.5 miles dedicated to each. Materials were matched with either Utah Blend beads or Utah Blend with Wet Reflective optics, though waterborne paint did not use wet reflective elements in accordance with standard VTrans policy. The markings were placed in August 2014, meeting all environmental requirements at the time of installation. Waterborne, MMA, polyurea, and epoxy markings were applied using automated truck-mounted systems, while thermoplastic was applied using a handcart across the full three-mile thermoplastic test section. Each test site included both white and yellow edge lines, with retroreflectivity measurements and visibility wear assessments taken every 20 feet. Readings were recorded on the day of installation and then weekly for the first month. Thereafter, readings were taken monthly, seasonally after six months, and again after two years.

VTrans standard practice for interstate highways includes the use of truck plows with carbide edge blades, with a tow plow available for rotation if needed. Anti-icing with salt brine and deicing with solid NaCl are most common. In rare circumstances of extreme cold, abrasives are placed for safety. These operations are adjusted based on weather and pavement conditions. During the winter months following the application of the pavement markings on I-89 SB, the VTrans Districts recorded the amount of salt, brine, and sand used on the highway. Data was collected from November 11, 2014, to February 23, 2015, a total of 102 days out of which the snowplow trucks were deployed 51 times. Of those, the trucks used their plows for 49 days, salted on all 51 days, and applied brine on 14 days. From this period, they recorded that winter maintenance occurs roughly 50% of the days, with 14 tons of salt 11 used per application day, or one ton of salt per mile on application days. While not the full duration of the winter season, this period offers a representative snapshot of Vermont's typical winter maintenance intensity.

These winter operations caused substantial damage to certain marking systems evaluated in this project. Thermoplastic markings, especially those surface-applied, exhibited extensive delamination and retroreflectivity loss, requiring full replacement by May 2015. Waterborne markings also exhibited rapid decline, with some sections losing up to 96% of their initial retroreflectivity after a single winter and requiring repainting. In contrast, polyurea and epoxy emerged as the top-performing materials, particularly in recessed configurations. In terms of service life, waterborne and thermoplastic lasted 8 months, MMA lasted 15 months, and epoxy and polyurea lasted 35 months. Although wet reflective optics were expected to outperform Utah blend in wet conditions, test results were mixed. In some cases, Utah blend optics even showed higher wet retroreflectivity than wet reflective elements, prompting the researchers to recommend further investigation.

Overall, the study reinforced the importance of recessing markings in climates with heavy winter maintenance. The study highlighted that yellow recessed polyurea with wet reflective optics yielded the best performance in terms of nighttime visibility and durability.

Pavement Marking Comparison Study – US Route 302 Bike Lane Markings^[14]

Another field study concluded in 2018 compared three green-colored pavement marking materials for bike lanes along US Route 302 in Berlin, Vermont. The goal was to assess constructability, durability, and long-term performance under local environmental stressors and use the results to provide recommendations regarding future usage in Vermont.

The materials evaluated included PreMark (a preformed thermoplastic from Ennis-Flint), CycleGripMMAX (an MMA system also from Ennis-Flint), and Color-Safe (an MMA based system from Transpo Industries). All materials were installed between August and October 2016 on milled and paved asphalt surfaces. PreMark installation included brushing and blowing off the asphalt surface, applying an approved two-part sealer to remove unwanted moisture from the asphalt surface, and heating the symbols into place. It was installed at an ambient temperature of 80°F and approximately 90 mils thickness but was found to be sensitive to overheating, which could result in scorching. In contrast, CycleGripMMAX and Color-Safe were applied using hand tools such as rollers and squeegees, with a typical cure time of 20 to 60 minutes depending on ambient temperature and moisture conditions. Both materials were installed at a thickness of approximately 90 mils, with ambient temperatures ranging between 60°F and 70°F. Surface preparation included masking the inlaid pavement marking tape, laying out the bike lane blocks, and mixing the MMA compounds with catalyst and aggregate. Additionally, CycleGripMMAX was installed in accordance with the manufacturer's recommendation, following a 30-day waiting period after paving.

Two years after installation, the markings were visually evaluated for wear, bonding, cracking, and overall condition. PreMark showed the lowest durability across all locations. Notable issues included wearing, chipping, surface cracking, and delamination, likely due to differential expansion with the pavement, presence of moisture, and high traffic. CycleGripMMAX performed better, with no signs of delamination or cracking. Although some surface wear was noted in areas subjected to heavy turning movements, the markings remained mostly intact. Color-Safe appeared to be the best performer of the three. Even in high-volume intersections near Interstate 89, the markings retained their color, surface texture, and adhesion. No delamination or severe wear was observed, and all evaluation sites were rated in either "Good" or "Fair" condition after two winter cycles. Based on the results, VTrans concluded that MMA green bike material should be explored for future bike lane markings, when cost, time to use, and environmental factors permit.

While conventional pavement marking materials continue to improve in durability and retroreflectivity, each type has its own limitations. These challenges have led to growing interest in alternative technologies with improved resistance to mechanical and chemical damage. Cement-based pavement markings have recently emerged as one such option, with the potential for longer service life under harsh environmental and maintenance conditions.

Cement-Based Pavement Markings

Cement-based pavement markings are an emerging category of durable materials that use a hydraulic binder similar to portland cement which bonds chemically to the pavement surface. Once cured, the coating forms a dense, mineral-like layer that resists abrasion, ultraviolet degradation, and deicing chemicals. Being inorganic and non-thermoplastic, the cured material does not soften under heat or deform under plow contact, making it well suited for regions where repeated snowplowing and freeze-

thaw cycles accelerate deterioration of conventional markings. At the time of this review, Enduramark was the only commercially available cement-based pavement marking product in the market [6, 7, 8].

The material is supplied as a dry powder, composed primarily of portland cement, along with other components such as calcium carbonate, calcium metasilicate, ferric oxide pigments, and copolymers. It is mixed with 17% to 20% water by weight prior to placement and can be spray-applied at 35-40 mils using conventional paint or thermoplastic guns and extruded at 60 mils with modifications to current pavement marking equipment and trucks. Additionally, it can be placed directly over existing pavement markings, eliminating the need for grinding or primers. It may also be installed on wet pavement at ambient temperatures. Once applied, the material cures through hydration and develops traffic-ready strength within 30 to 60 minutes, depending on environmental conditions. A portion of the base marking material can be replaced with a fast-setting additive of similar composition to reduce dry time to approximately 5 to 15 minutes. However, in general, longer cure times tend to result in stronger adhesion to the pavement surface.

Manufacturer-reported laboratory testing shows compressive strength greater than 3,100 psi, tensile strength above 700 psi, bond strength to asphalt and concrete exceeding 250 psi, and length change below 0.024%, indicating dimensional stability and adhesion. Freeze-thaw and scaling tests showed no surface distress or debonding, confirming resistance to moisture- and temperature-induced damage. A solar reflectivity index greater than 0.29 further supports optical stability and color retention under ultraviolet exposure. Complementing the lab data, field evaluations conducted in Michigan and New Jersey, summarized in section 2.3, demonstrated multi-year durability with minimal surface wear or bead loss after multiple winters of snowplowing.

The material is nonflammable, noncombustible, and low-VOC (<50 g/L), presenting minimal worker or environmental hazards. It is classified as non-hazardous under OSHA's Hazard Communication Standard (HCS), although the use of gloves, goggles, and respirators is recommended to limit exposure to alkaline dust or wet-cement contact.

Regarding installation and equipment-related costs, no documented unit prices or bid histories were identified during this review. When ARA approached the manufacturer for additional information, the manufacturer provided a route estimate for installation of a 6-inch cement-based marking line with Quick Set and Type I glass beads at 60 mils thickness. Table 2 compares this estimate with the installation cost of a 6-inch polyurea white line for a project quantity of approximately 350,000 LF. The polyurea values were obtained from recent Vermont bid details^[15]. It should be noted that the polyurea unit price in Table 2 is lower than the 4-inch line marking price shown in Table 1 due to the larger project quantity.

Table 2. Marking Installation Cost Comparison.

Marking Material	Average Price (per LF)
Polyurea	\$0.95
Polymer-Modified Cement	\$1.30

Nevertheless, these values should be considered only indicative estimates, as actual costs may vary depending on factors such as project size, contractor setup, location, and application method. The manufacturer also noted that the cement-based marking material is compatible with modified versions of standard paint or thermoplastic striping equipment and that trial installations are offered at competitive pricing to help agencies evaluate performance and operational fit. Two dedicated application

trucks are reportedly available; however, commercial availability and pricing details have not yet been released.

From a striping contractor's perspective, several practical considerations remain. Converting existing equipment to apply a different marking material is often not straightforward and may result in significant downtime and logistical complexity. Additional operational requirements, such as transporting a water truck to the site, further contribute to overall costs. To date, specialized equipment for this type of application is not readily available among contractors in the New England region, and existing durable marking trucks already represent a substantial capital investment, often exceeding \$750,000. Acquiring additional equipment without a sustained workload may be difficult to justify.

Field Evaluations

As part of this literature review, ARA contacted multiple state and local agencies, including the Michigan Department of Transportation (MDOT), Georgia Department of Transportation (GDOT), New Jersey Department of Transportation (NJDOT), and Bergen County, New Jersey, that have expressed varying levels of interest in cement-based pavement markings. While GDOT and NJDOT have not yet identified suitable projects for evaluation, both agencies mentioned that they were aware of the product and expressed preliminary interest in considering it for future durable marking applications. MDOT and Bergen County have completed several field installations of the marking material and shared performance observations from those evaluations. Additionally, ARA reviewed AASHTO DataMine records for both white and yellow cement-based markings that are part of an ongoing three-year evaluation on asphalt and concrete test decks. The findings from these sources are summarized below.

Michigan DOT ^[4]

MDOT was first introduced to cement-based markings when a contractor placed it as a special marking material in Detroit around 2018. It was initially used for green bike lanes, decorative brick-patterned crosswalks, simulated islands, bus stops, and the Spirit Plaza mural, among other colored applications. The agency noted that the dry time was weather dependent and relatively long, but once cured, the markings performed well for several years with good color stability and minimal surface distress. Field observations also indicated that the preparation process could be time-consuming. The crew had to manually load and mix cement powder, aggregate, water or ice, and dye, sometimes by trial and error to achieve the desired color tone. While the crew likely refined the dye ratio for commonly used colors like green over time, custom colors such as the brick-red crosswalks required considerable effort to match accurately. Furthermore, although the spray hose allowed for quick placement in simple shapes (e.g., boxes), downtime increased when color changes were needed, such as when switching to white for bicycle symbols.

The product was subsequently used for recessed longitudinal pavement marking installations in 2019, primarily on concrete roundabouts. At the time, cure time remained relatively slow. In terms of performance, MDOT reported that the markings retained nearly 100% material coverage after five years of service, whereas polyurea markings on adjacent ramps exhibited wear and chipping. Retroreflectivity measurements showed a gradual decline over time, suggesting that optical degradation rather than material loss would likely determine the restriping interval. They also observed that grooving the material helped protect the optical media from plow contact and improve long-term bead retention.

The marking material was also surface-applied at high-traffic HMA locations, including the US-24 to I-75 ramps, where vehicles frequently off-track onto the markings to evaluate its durability. Visually, the durability of the material at these sites was equivalent to that of grooved installations, though slightly faster bead loss was noted in photographic documentation.

Based on field performance to date, MDOT estimates a service life of at least five years. Their ongoing evaluations include testing the cement-based marking material with an additive intended to accelerate curing, reducing dry time to approximately 3 to 4 minutes. However, sufficient long-term data has not yet been collected to determine whether the use of additive impacts durability or bead retention.

Bergen County, New Jersey ^[2]

Bergen County initially adopted cement-based pavement markings for use on bridge decks, decorative crosswalks, and high-friction surface treatments. After observing favorable performance in those applications, the county extended their use to longitudinal markings starting in 2020. Since then, the material has been installed at multiple locations, representing a variety of pavement types, traffic volumes, and environmental conditions. In some locations, high-performance glass beads were used to enhance nighttime brightness. These beads are typically incompatible with thermoplastic markings due to poor adhesion.

At the time of application, the drying time was reported to be approximately 10 minutes, during which traffic cones were used to restrict vehicles from entering the work zone.

Photos of the pavement markings, including microscopic images of retroreflective bead embedment, were taken along with retroreflectivity measurements to evaluate performance. In addition, the engineer conducted nighttime site visits to compare the visibility of cement-based markings with that of thermoplastic, which is also used by Bergen County. The county documented its findings in a February 2024 internal report, supplemented with additional observations after the 2024–2025 winter season.

Based on the findings, the material demonstrated excellent field performance through multiple winter cycles. While the daytime appearance was similar to thermoplastic, the cement-based markings maintained it for a much longer duration. Minor localized failures were reported during the winter of 2024, particularly in areas where the cement-based marking material was placed over aged thermoplastic. These issues could be attributed to unusually high snowplow activity that season, approximately 14 events, compared to typical four plowing events in 2023.

Key examples of durability, as documented in the supplemental report after evaluation on April 2025, include the following:

1. **River Road, Teaneck (Installed 2020):** Markings demonstrates substantial line presence after five years of service, while the adjacent thermoplastic markings required replacement after two years due to wear. Retroreflectivity readings for this site remained around 180 mcd/m²/lux through August 2023, before dropping below 100 mcd/m²/lux following the 2024 winter season.
2. **Main Street, Bogota (Installed 2022):** Retroreflectivity readings ranged from 250 to 400 mcd/m²/lux. Although this is lower than the peak values exceeding 600 mcd/m²/lux observed through February 2024, the reduction could be attributed to repeated snowplow passes.

3. **Overpeck Park, Leonia (Installed 2022):** Markings were successfully applied over deteriorated and irregular thermoplastic and continued to show strong visibility and retroreflectivity above 200 mcd/m²/lux.
4. **Ramapo Valley Road, Mahwah (Installed 2022):** Applied on new asphalt using Type 1 and Duralux high refractive index beads, the markings showed remarkable resilience. Even after three winters and extensive snow removal, the yellow marking retroreflectivity remained in the mid-300s.

The county also noted that unlike thermoplastic, cement-based markings retained flexibility that aligned with the thermal expansion and contraction of asphalt, minimizing cracking and hazing. It provides a robust pavement marking material that withstands wear for a considerably long time and comes with a 3-year manufacturer's warranty. Further, the convenience of installing the markings on existing thermoplastic enabled Bergen County to incorporate cement-based markings into its restriping program.

As of 2025, the county continues to install cement-based markings at additional sites, including both newly paved asphalt and existing thermoplastic surfaces. The manufacturer and installer believe that the material has the potential to match the service life of the underlying asphalt pavement with a single application.

AASHTO Datamine Information ^[1]

Cement-based pavement markings (white and yellow) are currently being evaluated through the AASHTO Product Evaluation and Audit Solution under DataMine Numbers PMM-2024-01-099 (white) and PMM-2024-01-100 (yellow). Both materials are classified as polymer cement-based pavement markings composed of polymer binders, fibers, mineral aggregates, and pigments. Product application information specifies optimal pavement surface temperatures for installing the marking material range between 45°F and 120°F.

The ongoing study is a three-year field performance evaluation conducted on asphalt and concrete pavement decks in West Virginia. Field installations were completed in May 2024 under controlled conditions:

- Air temperature: 75°F to 80°F
- Road temperature: ~82°F
- Relative humidity: 41% to 49%
- Application thickness: 60 mils
- Application type (surface/recessed): Surface-applied
- Bead data:
 - Bead manufacturer - Potters
 - No other bead information was provided

Inspection data collected through June 2025 indicated excellent durability across both substrates, with all sites maintaining a durability rating of 10 out of 10 across each inspection interval during the first 13 months. Dry retroreflectivity values for both white and yellow markings exhibited a consistent trend: an initial increase to peak values within 3 to 5 months, followed by a gradual decline by the one-year inspection. This pattern reflects typical bead embedment and surface wear cycles characteristic of durable pavement marking systems. Wet retroreflectivity values, in contrast, were more variable and

did not exhibit a consistent trend. For white markings, wet retroreflectivity ranged from 17 to 264 mcd/m²/lux, and for yellow markings, values ranged from 16 to 108 mcd/m²/lux.

The following tables (Table 3 & Table 4) summarize the average dry retroreflectivity values and durability ratings recorded during the first year of evaluation at three key test intervals. The values represent averages across skip and wheel test paths.

Table 3. Average dry retroreflectivity and durability of white cement-based markings.

Test Date	Dry Retroreflectivity (mcd/m ² /lux)		Durability (1-10)	
	Asphalt	Concrete	Asphalt	Concrete
5/28/2024	416	428	10	10
9/09/2024	613	666	10	10
6/10/2025	385	395	10	10

Table 4. Average dry retroreflectivity and durability of yellow cement-based markings.

Test Date	Dry Retroreflectivity (mcd/m ² /lux)		Durability (1-10)	
	Asphalt	Concrete	Asphalt	Concrete
5/28/2024	210	284	10	10
9/09/2024	379	375	10	10
6/10/2025	298	279	10	10

Color measurements, including both daytime and nighttime CIE data, remained stable throughout the monitoring period, indicating strong pigment retention and optical stability under UV exposure and environmental conditions.

Overall, these early AASHTO evaluation results confirm that the marking material maintained high optical and physical integrity throughout its first year of testing. These findings align with field observations from state and county agencies regarding its durability and long-term visibility. Continued monitoring through 2027 is expected to provide additional insights into multi-year trends.

The findings from laboratory and field evaluations collectively indicate that cement-based markings represent a durable, high-performance alternative to conventional pavement marking materials. While early results are encouraging, continued multi-year monitoring and life-cycle cost analysis will be essential to fully assess their long-term durability and economic viability.

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