PREVENTATIVE MAINTENANCE TREATMENTS

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STATE OF VERMONT
AGENCY OF TRANSPORTATION

RESEARCH & DEVELOPMENT SECTION

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The work within this report was conducted in response to the 2006-R-02 Work Plan. The content of the report was prepared in 2015. After a 2017 review by the Materials Section and current Research Section, the report is being released.

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16. Abstract

Historically, traditional pavement maintenance practices have focused primarily on structural or corrective activities typically performed after a deficiency occurs in the pavement such as extensive cracking, rutting or loss in friction. However, with increasing demands to our roadway network and decreasing resources, the system cannot continue to operate with traditional approaches. Preventative maintenance treatments (PMTs), intended to arrest minor deterioration, retard progressive failures, and reduce the need for corrective maintenance, has the potential to both improve quality and reduce expenditures. The life cycle and associated cost-effectiveness of PMTs may vary significantly based upon the selected treatment, functional classification, traffic demand, condition of the roadway prior to application, constructability and environmental conditions.

This evaluation focused on the constructability, performance and cost effectiveness of NovaChip®, a paver placed surface treatment, Slurry Seal, a microsurfacing Type I treatment, and a thin hot mix asphalt (HMA) overlay, a standard mill and fill treatment. The treatments were not placed in areas with the same pre-existing distress failures. This paired with product interference during application of the Slurry Seal treatment contributed to the poor comparability of the treatments and resulted in premature failures of the Slurry Seal. It should be noted that the NovaChip® treatment at the time of installation was a patented proprietary product, however since the time of application the patent has expired.

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ABSTRACT

Historically, traditional pavement maintenance practices in Vermont focused primarily on structural or corrective activities typically performed after a deficiency occurs in the pavement such as extensive cracking, rutting or loss in friction. However, with increasing demands on our roadway network and decreasing resources, the system gradually deteriorates with traditional approaches. A downward trend in overall network condition was directly associated with an investment strategy to correct failed pavements once heavily deteriorated with lower emphasis placed on optimizing pavement life. Preventative maintenance treatments (PMTs), arrest minor deterioration, retard progressive failures, and reduce the need for corrective maintenance. This incremental protection strategy has the potential to both improve network quality and reduce individual project expenditures. The life cycle and associated cost-effectiveness of PMTs may vary significantly based upon the selected treatment, functional classification, traffic demand, condition of the roadway prior to application, constructability and environmental conditions.

This evaluation focused on the constructability, performance and cost effectiveness of 4 specific techniques. NovaChip® paver placed surface treatment, Slurry Seal microsurfacing Type I treatment, and a thin hot mix asphalt (HMA) overlay, a standard mill and fill treatment. Each of the techniques was placed in areas with similar traffic but different pre-existing distress conditions. This paired with interferences during construction prevented an accurate evaluation of the Slurry Seal treatment. Poor comparability of the treatments resulted. Premature failures of the Slurry Seal due to construction issues and early interventions for preservation before exhaustion of life cycle limited the statistical validity of the comparisons.

INTRODUCTION

The Vermont Agency of Transportation's (VTrans) mission is to provide for the movement of people and commerce in a safe, reliable, cost-effective and environmentally responsible manner. One of the most crucial aspects in achieving this mission is to maintain an acceptable condition of one of the State's most valuable assets: the state's 3,200 miles of highway, which is managed by the Pavement Design Unit of the Highway Safety and Design Section of the Project Delivery Bureau. Traditional pavement maintenance practices have focused primarily on structural or corrective activities typically performed after a deficiency occurs in the pavement such as extensive cracking, rutting or loss in friction however, with increasing demands to our roadway network and decreasing resources, the system cannot continue to operate with traditional approaches.

Over time, the Federal Highway Administration (FHWA) as well as the US Congress has recognized the need to extend the service life of structurally sound pavement by preserving them using low cost treatments known as Preventative Maintenance Treatments (PMT). FHWA issued a memorandum dated October 8, 2004 summarizing the importance of PMT. It noted that timely preventative maintenance and preservation activities are necessary to ensure proper performance of the transportation infrastructure, increasing the return on investment (*1*). FHWA defines PMT in a memorandum dated September 12, 2005 as a planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system. These treatments are an essential piece of the pavement preservation approach. It is unlike its counterpart pieces:

1) Pavement Rehabilitation, which aims to enhance the structural or load capacity of an existing pavement by increasing pavement thickness to strengthen existing pavement sections; or
2) Routine Maintenance, consisting of planned maintenance on a routine basis, which might include cleaning adjacent roadway ditches or filling potholes.

This often increases the serviceability of the pavement but does not reduce aging of the pavement structure (*2*).

Preventative maintenance treatments (PMTs) are intended to arrest minor deterioration, retard progressive failures, and reduce the need for corrective maintenance, have the potential to both improve quality and reduce expenditures. The life cycle and associated cost-effectiveness of PMTs may vary significantly based upon the selected treatment, functional classification, traffic demand, condition of the roadway prior to application, constructability and environmental conditions (*3*).

Bituminous concrete pavements deteriorate over time. Each pavement structure is unique in terms of its underlying structure, climate, geographical location, and annual average daily traffic

(AADT). Due to the variability of pavement structures, it is important to understand the causations for specific distresses and factors that decrease a pavement's life-cycle. Pavement distresses include cracking, depressions, joint deterioration, pumping, shoving, flushing, bleeding, potholes, and rutting. Catalysts that greatly influence pavement distress are penetrating water, oxidation, and environmental factors such as heat, sunlight, freeze/thaw cycles, and salting.

The timing of placing PMT is vital in the success of the treatment. According to FHWA, an effective pavement preservation program will address pavements while they are still in good condition and before the onset of serious damage occurs. It must be, "a program employing a network level, long-term strategy that enhances pavement performance by using an integrated, cost-effective set of practices that extend pavement life, improve safety and meet motorist expectations (*2*)." The Long-Term Pavement Performance (LTPP) program was established by FHWA in 1987 to develop key recommendations for building and maintaining a cost-effective highway system. LTPP along with other studies have shown that the proper execution of a pavement preservation program using various PMTs will increase the life-cycle of certain pavements by extending the time until a corrective or reactive rehabilitation is needed. This not only results in overall cost savings, but increases user support based on better and longer pavement condition (*4*).

As illustrated in the graphs in Figure 1 and in Figure 2, when applied at the correct time, a PMT can prolong pavement life considerably.

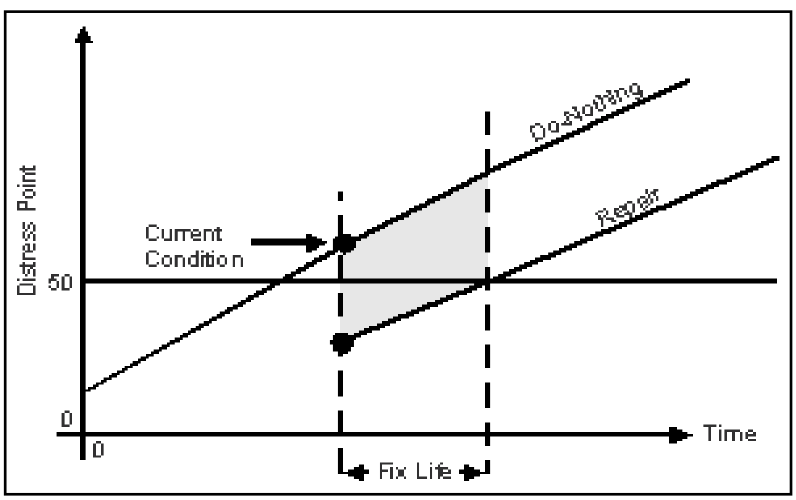

Figure 1: Preventative maintenance applied to an unsatisfactory pavement (*4*).

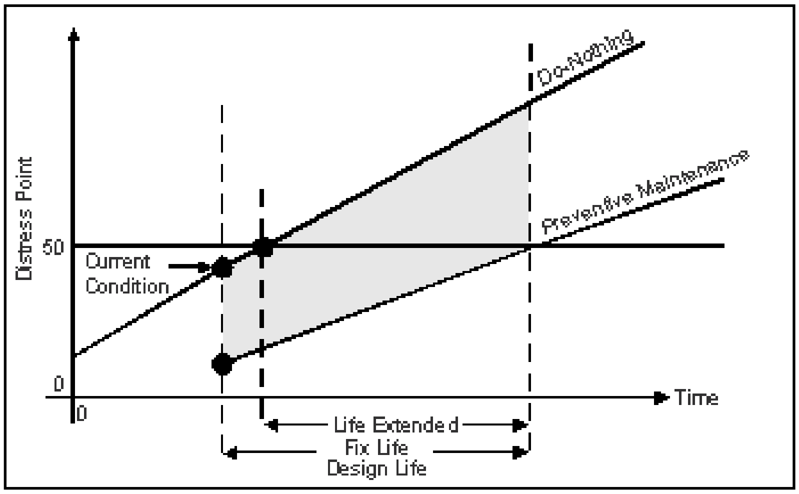

Figure 2: Preventative maintenance applied to a satisfactory pavement (*4*).

Because all PMTs are unique in terms of composition, application, overall durability, and associated costs, the overall effectiveness is dictated not only by the current surface condition of the roadway but the surface preparation, mix design, production and construction play a key role in the overall success.

The intent of this research initiative, WP 2006-R-2 was to evaluate the constructability, performance and cost effectiveness of

1) NovaChip®, a paver placed surface treatment;
2) Slurry Seal, a microsurfacing Type I treatment; and
3) Thin hot mix asphalt (HMA) overlay, a standard mill and fill treatment as compared to a control or untreated section.

The following report summarizes the condition of the preexisting roadway surface, construction details, performance including cracking, roughness, and rutting indices, and observations over the course of the evaluation.

PROJECT LOCATION AND SUMMARY

Project Location Description

The Williamstown-Montpelier pavement preservation project, IM SURF (2), was constructed between September and October of 2006 along I-89 southbound between MM 42.95 to MM 52.45, for a total length of 9.5 miles. The project included surface preparation and the application of three treatments including: Slurry Seal, NovaChip®, and Thin HMA Overlay. A control section was planned to be adjacent to the three treatments on the northern project limits, however during construction it was placed near the southern project limits and not adjacent to the experimental treatments. Because the section was moved to a different location, it was not used as a control section because the pavement had a different history and is not comparable to the other treatments. The experimental pavement maintenance treatments were constructed from MM 43.95 through MM 52.45. Bridges 36S, 37S, and 38S, within the limits were left untreated. NovaChip® was applied in both the passing and travel lanes, Slurry Seal was applied in the passing lane only, and the Thin HMA Overlay was placed in the travel lane only. The limits for each treatment are specified in Table 1.

Table 1: Surface Treatment Limits.

Treatment Type	Towns	MM From	MM To	Length (Miles)	Location
NovaChip®	Williamstown-Barre	43.95	48.25	4.3	Passing and Travel Lanes
Slurry Seal	Barre-Montpelier	48.25	52.45	4.2	Passing Lane Only
Thin HMA Overlay	Barre-Montpelier	48.25	52.45	4.2	Travel Lane Only

Historic Paving Information

Figure 3 illustrates the historic pavement structure. It should be noted that during the most recent paving rehabilitation project in 1998, granite stone from Websterville, VT was incorporated into the pavement mix from MM 46.9 to MM 53.75 and Monkton quartzite was used in the mix from MM 36.9 to MM 46.9.

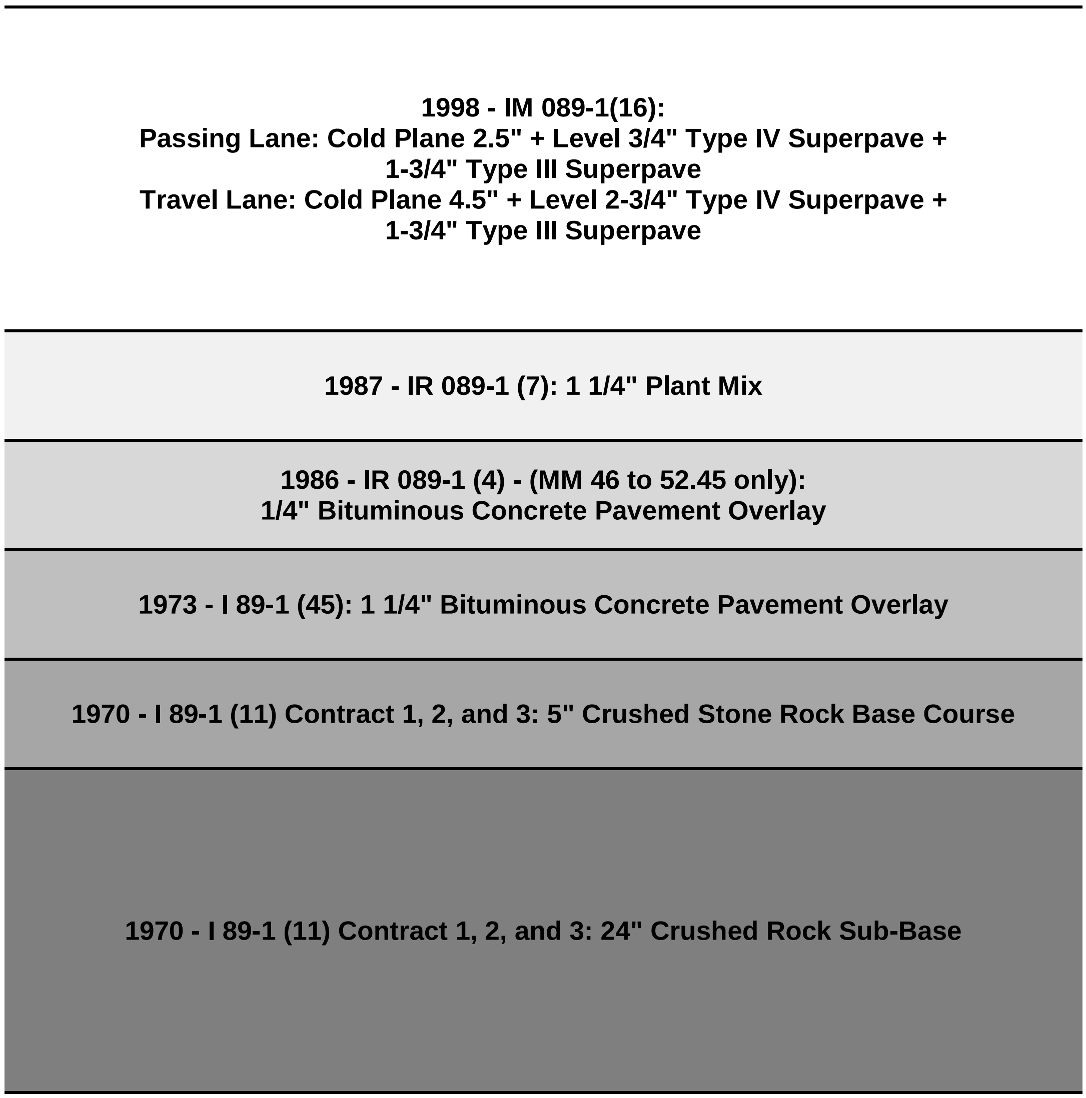

Figure 3: Historic paving profile.

MATERIAL DESCRIPTION

Various types of PMTs are available for flexible pavements including crack sealants, chip seals, slurry seals, micro-surfacing and ultra-thin bituminous overlays. Each of these treatments is unique in terms of composition, application, overall durability and associated costs. Their descriptions, advantages, disadvantages, and application processes and details are summarized herein.

Slurry Seal

Description

Slurry Seal is a cold-mix mixture of slow-setting emulsified asphalt, fine well-graded aggregate, mineral filler, and water (*4*). The treatment is used to seal surface cracks, stop raveling and loss of matrix, makes open surfaces impermeable to air and water, and improves skid resistance. It does not improve the structural strength of a pavement section (*5*). Slurry seal generally applied at 1/8" or 1/4" thicknesses (*5*).

There are three types of Slurry Seal: Type I, Type II, and Type III. The type is determined based on aggregate gradation. Typically Type I is used for maximum crack penetration in low-density traffic areas such as light aircraft airfields, parking areas, or shoulders Commonly, Type II is used to correct severe raveling, oxidation, loss of matrix, and to improve skid resistance. It is used in areas where traffic is moderate to heavy. Type III is applied to areas of heavy traffic to correct surface conditions. This project incorporated Type II Slurry Seal (*5*).

Advantages

- Rapid application (*5*).
- No loose cover aggregate (*5*).
- Ability to correct minor surface irregularities (*5*).
- Minimum loss of curb height (*5*).
- Reduces the number of construction joints by receiving a constant supply of material while the machine is working (*6*).
- Single pass operation (*7*).
- Can be constructed one lane at a time without matching lanes before opening traffic (*7*).

Disadvantages

- Provides no cross-slope correction (*7*).
- Difficult to obtain proper surface texture with hand tools (*7*).
- Requires at least 7 days for emulsion to fully cure before permanent markings can be applied (*7*).
- Equipment cannot account for shoulder breaks (*7*).
- Cannot be constructed at night (*7*).
- Curing time is dependent on environmental conditions and is significantly affected by sunlight exposure (*7*).

Application Process

Slurry Seal is applied using a traveling mixing plant with attached spreader box that spreads the slurry by a squeegee-type action. The machine is a self-contained, continuous-flow mixing unit capable of delivering predetermined material amounts accurately to the mixing chamber (*5*).

Prior to application, the pavement should be cleaned of all dirt, dust, mud spots, vegetation, and other foreign matter. An application of tack coat of diluted emulsified asphalt used in the Slurry Seal mix may be required directly ahead of the Slurry Seal. The air temperature should be 10°C (50°F) and rising and placed when no rain is expected within the cure time of the emulsion (*5*).

NovaChip®

Description

NovaChip® was developed in France in 1986 and first used in the United States in 1992. The once patented treatment, NovaChip® is described as an ultrathin paver-placed surface treatment, formulated of hot-mix asphalt with gap-graded aggregate placed on a polymer-modified asphalt emulsion tack coat. The total wearing surface thickness is 0.375 to 0.75 inches and is put down at high speed in one pass with a self-priming paver, ensuring thorough waterproofing of the pavement and high skid resistance (*5*). Ideal locations for NovaChip® would be pavements where ruts are less than 0.5 inches deep, moderate to no cracking, and minor or no bleeding (*8*).

Advantages

- Highly durable surface for high volume roads (*5*).
- Fully open to traffic within an hour (*9*).
- Excellent bonding to existing pavement (*10*).
- Minimal equipment for installation (*10*).
- Material is fully recyclable (*11*).
- Reduced rolling noise for traffic (*10*).
- The coarse aggregate matrix has excellent macro texture qualities resulting in good skid resistance and reduced backspray of roadway moisture and hydroplaning (*10*).
- Corrects minor road profile deficiencies (*12*).
- Suitable for both asphalt and concrete pavements (*12*).

Disadvantages

- Transportation limitation of 1.5 hours from mixing in plant to placement on the road (*5*).
- Minimum correction to cross-slope (*7*).
- Edges and transitions cannot be feathered (*7*).
- Coarse surface texture reduces pavement marking yield (*7*).
- Previously a patented treatment. The proprietary product required special equipment and installation license, often leading to increased cost and limited project availability (*12*).

Application Process

NovaChip® is produced at a conventional hot mix-asphalt production plant and is delivered on-site in a conventional hauling truck and transferred into a self-priming paver using polymer modified binder. The paver must be capable of spraying the polymer modified asphalt emulsion, applying the paver place mix, and smoothing the mat surface at a rate of 32.8 feet per minute (*13*).

The project special provision specifications state that NovaChip® can be placed once the surface temperature of the existing pavement is 45°F and rising. The paver first applies the polymer modified asphalt emulsion uniformly across the surface at a rate of 0.016 to 0.027 gal/ft^2 and at temperatures of 140°F to 176°F. The paver place mix should be placed at 293°F to 338ºF immediately after the emulsion. Once placed, a steel-wheeled double-drum roller weighing at least 10 tons will make a minimum of two static passes. Compaction, in two static passes should begin immediately after the application of the wearing course. Further, compaction must be completed before the mat temperature falls below 176°F (*13*).

Thin Hot Mix Asphalt (HMA) Overlay

Description

This treatment is commonly dense graded hot-mix asphalt that protects the existing pavement structure and improves ride quality (*4*). Typically, the overlay consists of plant-mix asphalt cement and aggregate. Frequently, specialized PG binders are specified to increase the toughness of the mix including polymer modification. The maximum nominal aggregate size is 3/8-inch (9.5mm) or less to provide for proper compaction of thin lift HMA. HMA mixtures can be broken into three general categories, each distinguishable by their aggregate gradation: dense-graded, open-graded and gap-graded mixes. Dense-graded gradations represent a full range of sieve sizes. Open-graded mixes consist mostly of particles of one size, usually porous, which allows water to infiltrate, thus reducing hydroplaning (*14*). Gap-graded aggregate contains both fine and coarse particles and is used in stone matrix asphalt mixes along with a stabilizer. When the surface is segregating or raveling, or block cracking is present, milling the surface is often recommended prior to placing the HMA overlay (*15*).

Advantages

- Works well in all climate conditions with proper weather (*16*).
- Provides a minor amount of structural enhancement (*17*).
- Marginally effective for almost all pavement conditions and distresses (*17*).

Disadvantages

- Subject to delamination, reflective cracking, and maintenance issues (*16*).
- Curb and bridge clearance may be an issue if the pre-existing pavement is not milled prior to placing the treatment (*16*).

Application Process

The application process follows common overlay paving practices in Vermont. When the thin HMA overlay is put down at a thickness of 0.75 to 1.5 inches it is considered to be a PMT. Again, prior to placing the overlay, milling of the pre-existing pavement is often recommended.

CONSTRUCTION

Pre-Construction

The project was awarded to the sole bidder, Pike Industries, Inc. headquartered in Belmont, NH on August 4, 2006. The mid-season bid process time period put time restrictions on the project which potentially compromised the successfulness of the treatments.

Crack sealing in all treatment locations occurred on September 5 and 6, 2006 by a subcontractor, Nicom Coating Corporation of Berlin, VT. Ideally, all cracks should be filled at least three months prior to the application of slurry seal. Early placement of crack sealing assures proper hardening and aging of the surface of the material prior to placement of any overlay.

VTrans project special provision specifications require proper surface preparation including thoroughly cleaning the surface to be treated to ensure it is free of dirt, oil, debris, and other foreign materials is essential to treatment success (*13*).

Slurry Seal

A sub-contractor, Sealcoating, Inc. of Braintree, Massachusetts applied the Slurry Seal on September 11 and 12, 2006. Specifications require that the treatment be applied when the temperature is 50°F and rising and stay above 50°F for a period of 24 hours after application during its cure time. For the first day of application, temperatures dropped below 50°F at approximately 8pm that evening until 10am the following day. The low temperature during this period was 38°F. On the second day of application the temperature again fell below 50°F at approximately 8pm and did not rise above 50°F until 9am the next day (*19*). According to the Daily Work Report no other issues were reported during construction (*20*). Figure 4 and Figure 5 show the paving process and completed top finish. Note the condition of the slurry seal in Figure 4 especially the brown hue.

Figure 4: Slurry Seal paving.

Figure 5: Completed Slurry Seal.

NovaChip®

A sub-contractor, All States Asphalt Inc. of Sunderland, Massachusetts placed NovaChip®, the paver placed surface treatment, on September 20, 21, and 22, 2006. Temperatures during application were above the required 45°F and rising. The material was placed on the roadway surface using a self-primer paver. It was immediately rolled using one 12 ton steel-wheeled double-drum roller that made one static pass. No issues were reported regarding the application (*20*). Figure 6 and Figure 7 show the paving process and completed top finish.

Figure 6: NovaChip® paving.

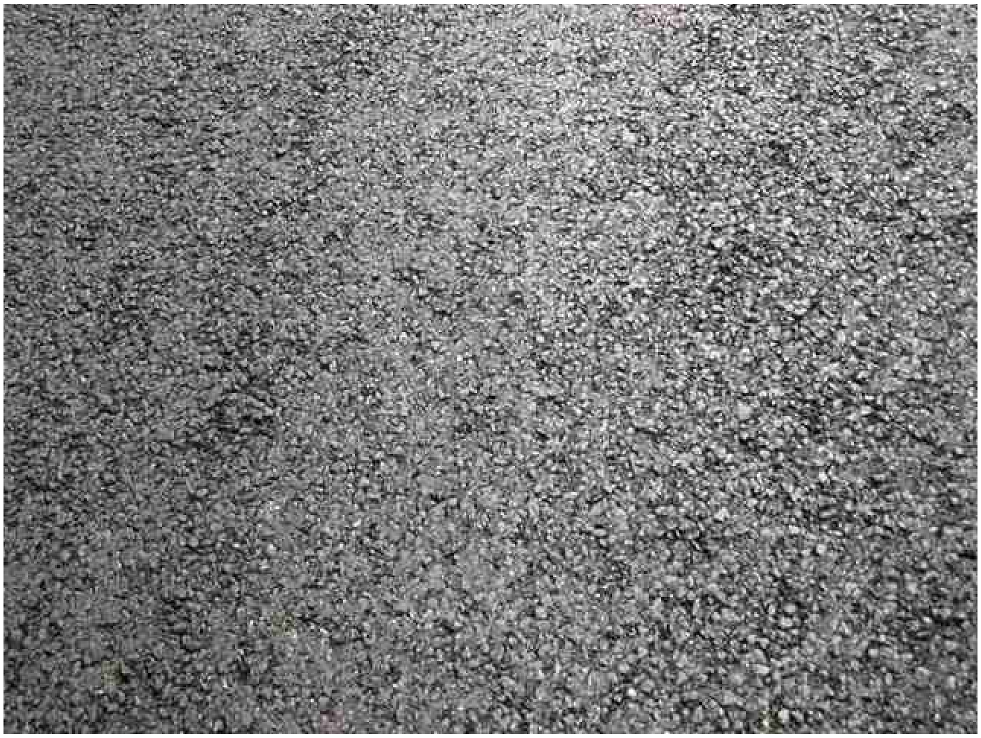

Figure 7: Completed NovaChip®.

Thin HMA Overlay

The prime contractor, Pike Industries, Inc. cold planed on October 16 and 17, 2006. Due to rain, paving did not occur on consecutive days and was completed on October 19, 24, 25, and 27, 2006. Research personnel were not on site for construction therefore photograph documentation and associated notes are omitted. However, like the other two treatments, no issues were reported (*20*).

PERFORMANCE AND OBSERVATIONS

Annual site visits and pavement performance data was used to evaluate the three PMTs within this project. The site visits included collecting photographs and noting specific distresses annually. Pavement performance data, through either contracted or in house was collected prior to construction and yearly throughout this project. The following includes a summary of observations and data analysis efforts.

Pavement Condition Index (PCI)

To quantify the condition of the pavement network in Vermont, VTrans contracts with a consultant to collect automated condition data including cracking, rutting, and roughness values statewide, as described herein. The severity levels of the values are utilized to calculate the overall Pavement Condition Index (PCI) and assess the performance and service life of pavement treatments across Vermont. Table 2 describes the different PCI levels and associated values.

Table 2: Pavement Condition Indices (PCI) Descriptions.

Good	Fair	Poor	Very Poor
Like new pavement with few defects perceived by drivers.	Slight rutting, and/or cracking, and/or roughness become noticeable to drivers.	Multiple cracks are apparent, and/or rutting may pull at the wheel, and/or roughness causes drivers to make minor corrections.	Significant cracks may cause potholes, and/or rutting pulls at the vehicle, and/or roughness is uncomfortable to occupants. Drivers may need to correct to avoid road defects.
PCI: 80-10	**PCI: 65-79**	**PCI: 40-64**	**PCI: 0-39**

In previous years, interstate and state route data was collected on alternating years in 1/10th (0.10) of a mile segments. Beginning in 2009, the scope of the collection cycle changed to annually for all state and interstate routes in 1/20th (0.05) of a mile segments. Therefore, this evaluation does not include PCI for structural and transverse cracking and the overall PCI is modified, calculated using only IRI and rutting values from the VTrans owned Dynatest pavement profiler. The accuracy between the equipment is tested each year and the values are within 3% of one another.

As shown in Figure 8, the Slurry Seal treatment reached the preconstruction PCI value by 2007, one year after construction. The Thin HMA Overlay section reached preconstruction values 7 years after application and the NovaChip in the travel lane reached the conditions eight years after application. NovaChip in the passing lane faired the best, averaging 25 more than preconstruction conditions at the conclusion of the study.

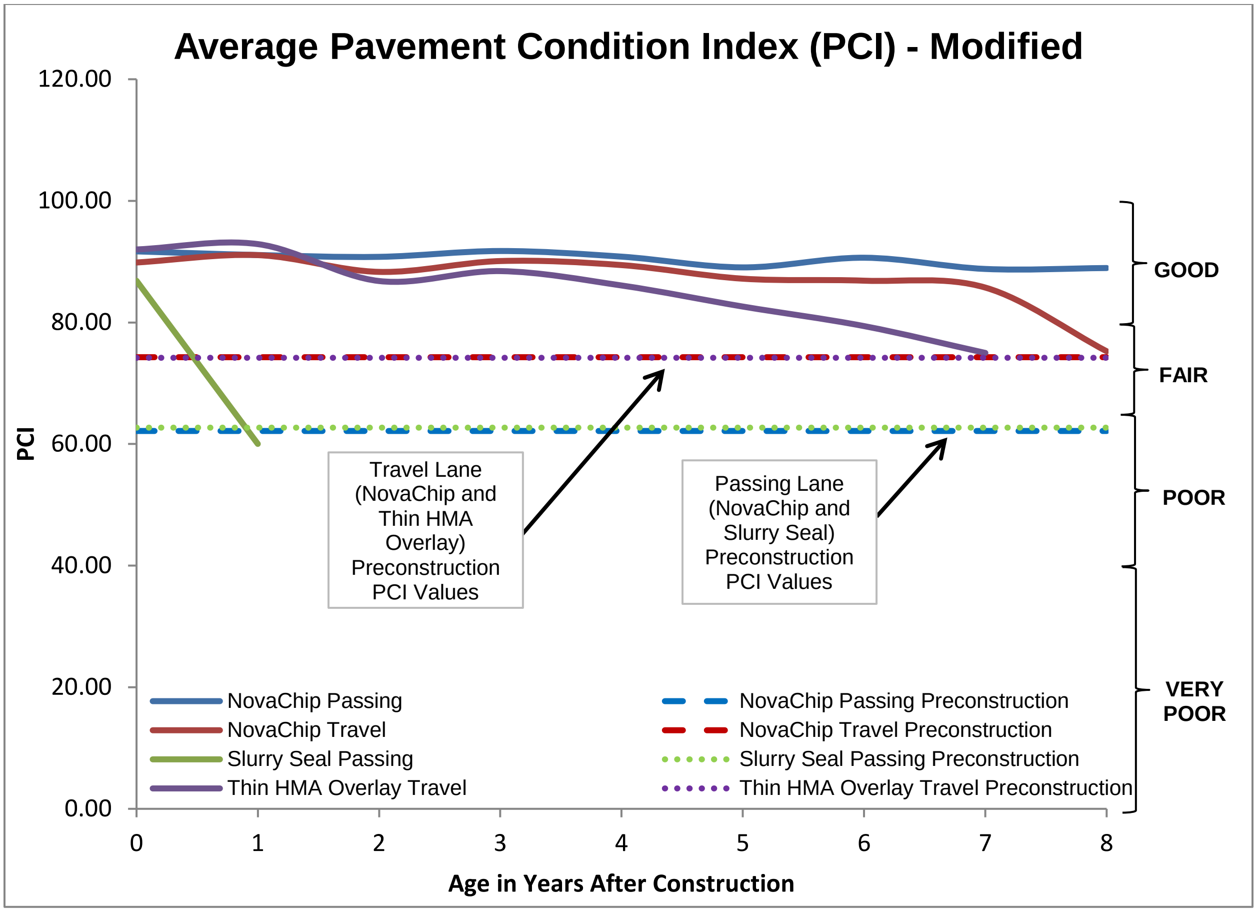

Figure 8: Overall Modified Pavement Condition Index (PCI).

Cracking

There are several causes for cracking in flexible pavements, including inadequate structural support such as the loss of base, sub-base, or sub-grade support, increased loading, inadequate design, poor construction, or poor choice of materials. This analysis provides an analysis of the comprehensive, structural, and transverse cracking indices.

Structural or fatigue cracks run parallel to the laydown direction within the wheelpaths or a small block pattern and are usually a type of fatigue or load associated failure. Transverse cracks run perpendicular to the pavement's centerline and are usually a type of critical-temperature failure or thermal fatigue that may be induced by multiple freeze-thaw cycles. In all cases, cracks allow for moisture infiltration and can result in structural failure over time.

As seen in Figure 9, the Slurry Seal section had significant wear within the first year of application. Preconstruction values were considered to be "very poor" in the PCI scale, averaging 45.96. One year after application, the treatment did not perform substantially better than preconstruction conditions, averaging 39.12. The other treatments far outperformed the Slurry

Seal. All treatments exhibited consistent Structural PCI values throughout the course of the study. At the end of the evaluation, all treatments were in the high end of the good PCI category, averaging 95-98.

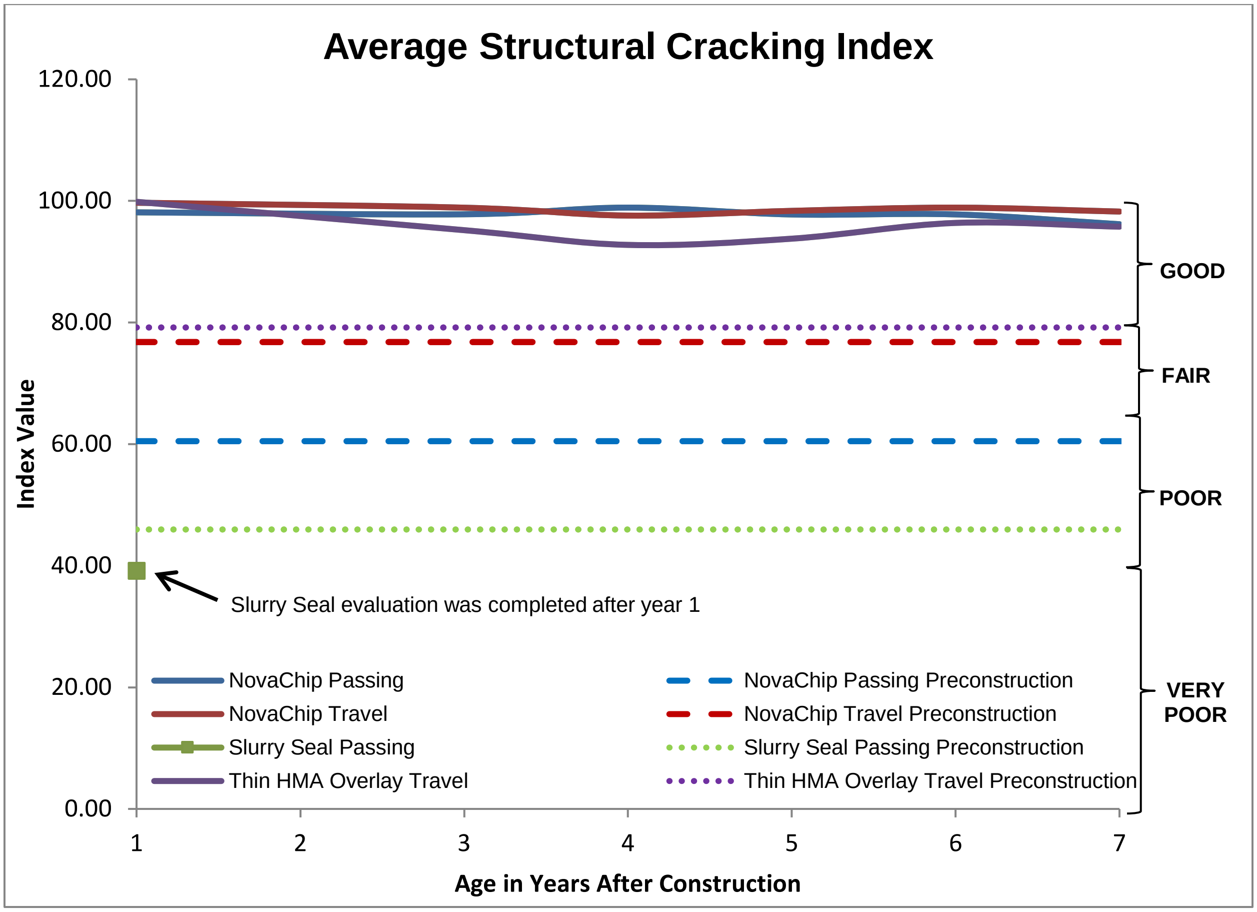

Figure 9: Structural Cracking Index.

As seen in Figure 10, Slurry Seal preconstruction transverse cracking values similar to the structural cracking values were also considered to be "very poor" in the PCI scale, averaging 41.29. One year after application, the treatment did not perform better than preconstruction conditions, averaging 34.78. Again, the other treatments far outperformed the Slurry Seal in this category. The NovaChip in the travel lane and Thin HMA Overlay treatments exhibited fairly consistent Transverse PCI values throughout the course of the study. The NovaChip in the passing lane was slightly lower but still in the good category over the duration of the evaluation, averaging 92.16 at the end of the evaluation. The other two treatments averaged 98-99 at the end of seven years after application.

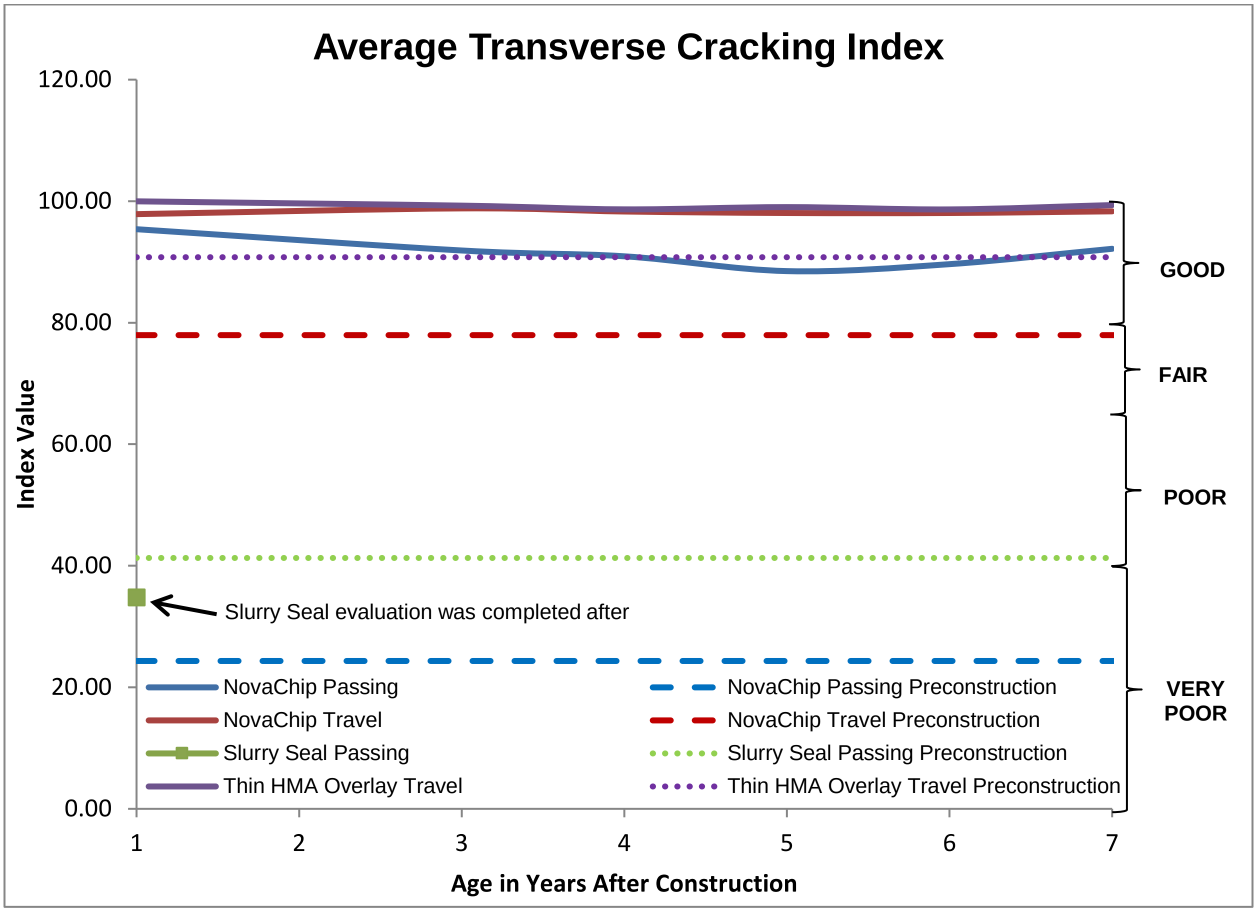

Figure 10: Transverse Cracking Index.

Rutting

Rutting is generally caused by permanent deformation within any of the pavement layers or subgrade and is usually caused by consolidation or lateral movement (shoving) of the materials due to traffic loading. The data collection scope of work describes a rut as a longitudinal surface depression in the wheel path of a pavement surface. Rut depth is defined as the distance from the lowest measured point within a wheelpath to an imaginary line extending from the pavement elevation at the center of the lane to the pavement elevation at the outermost (left or right) measurement, shown in Figure 11 (*21*).

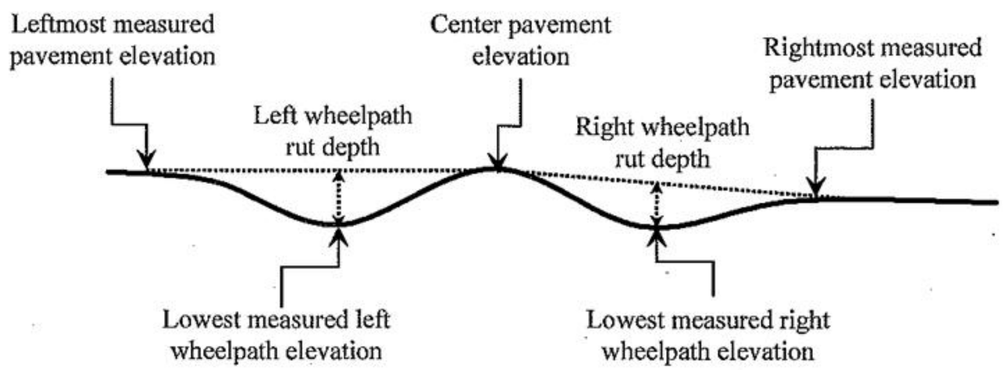

Figure 11: Rut depth measurements.

Rutting values (see Figure 12) were noted to be far more variable between treatments over the evaluation period. The Slurry Seal ended with a value of 83.26; however, this was one year after application. NovaChip in the passing lane performed the best, ending at a value of 94.45 at the end of eight years after application. NovaChip in the travel lane ended in the Fair/Good range. The Thin HMA Overlay section sharply decreased beginning at two years after application, ending with a 23.08 value seven years after application.

Table 3 summarizes the average rut values measured in inches. Like the index values, the Thin HMA Overlay section fared the worst over the seven-year evaluation, concluding with 0.798-inch average. The NovaChip sections were fairly consistent over the course of the evaluation, the passing lane averaging 0.055 inches at the end of eight years and the travel lane averaging 0.323 inches.

International Roughness Index (IRI)

IRI, or International Roughness Index, is utilized to characterize the longitudinal profile within wheelpaths and constitutes a standardized measurement of smoothness. According to AASHTO R 43M (*22*), "*an IRI statistic is calculated from a single longitudinal profile measured with a road profiler in both the inside and outside wheelpaths of the pavement*." All IRI values were collected in accordance with ASTM E950, Standard Test Method for Measuring the Longitudinal Profile on Vehicular Traveled Surfaces with an Inertial Profiler.

All treatments exhibited consistent average values during the evaluation (see Figure 13). The NovaChip in the passing lane was slightly better, averaging 83.44 at the end of the eight-year study where NovaChip in the travel lane averaged 82.87 and the Thin HMA Overlay averaged 81.71.

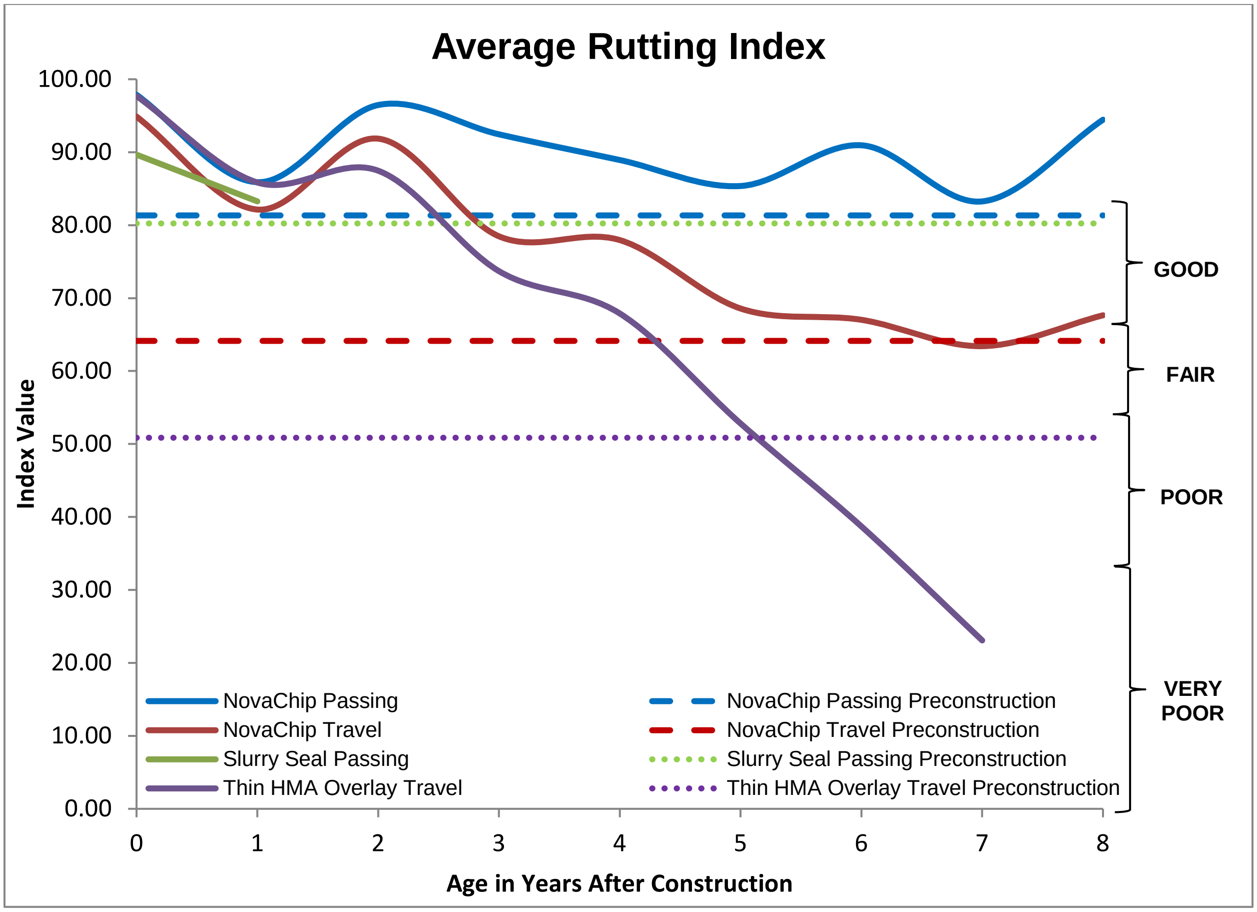

Figure 12: Rut Index.

Table 3: Average Rut Values (inches).

Year	Age	Passing		Travel	
		NovaChip	**Slurry Seal**	**NovaChip**	**Thin Hot Mix Asphalt Overlay**
Pre-Construction 2006	N/A	0.187	0.198	0.358	0.491
Post Construction 2006	0	0.021	0.103	0.051	0.023
2007	1	0.141	0.167	0.178	0.141
2008	2	0.035		0.081	0.125
2009	3	0.066		0.205	0.236
2010	4	0.101		0.211	0.312
2011	5	0.135		0.303	0.462
2012	6	0.091		0.329	0.616
2013	7	0.167		0.366	0.798
2014	8	0.055		0.323	

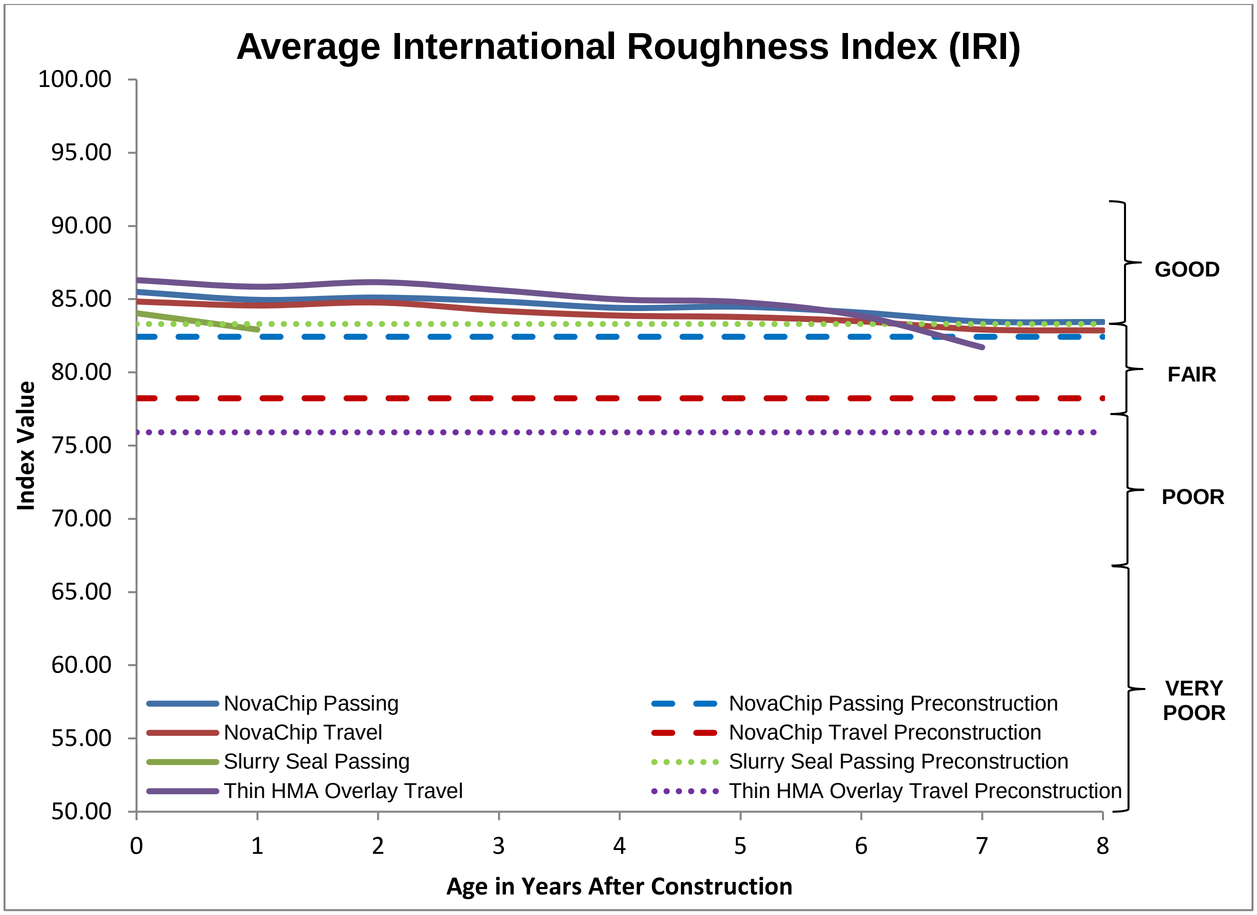

Figure 13: Average International Roughness Index (IRI).

Site Visit Observations

Pre-Construction

Prior to construction on April 11, 2006, the site was visited to characterize and document the existing condition and surface distresses of the site. Minimal cracking was noted at the site. Most cracks were longitudinal in nature and were primarily load related failures in the wheel paths. The cracks appeared to have received some sort of maintenance treatment to remediate them in the form of cold patch, hot mix, and/or crackfill. The hot mix patches appeared to have worked the best where the crackfill had begun to delaminate in areas. Aggregate stripping, creating an irregular surface and exposing additional aggregate in the pavement was observed throughout the project location (*23*). Figure 14 and Figure 15 show the site prior to construction.

Figure 14: Overview of the project site.

Figure 15: Repaired area.

1st Year Evaluation

The site was inspected by Research and Pavement Design Unit personnel on July 17, 2007. Within the Slurry Seal section, the treatment remained on approximately ½ to 2/3 of the lane, Figure 16. The areas that were crackfilled approximately one week before the treatment application were still sealed however the Slurry Seal had severely worn on both sides of the sealed crack in many areas, shown in Figure 17.

Figure 16: 2007 Slurry Seal and Thin HMA Overlay overview.

Figure 17: 2007 Crackfill in Slurry Seal section.

The Thin HMA Overlay and NovaChip® sections at this visit were noted to be in excellent condition. Wearing in the wheel paths due to traffic was noted in both sections, Figure 18.

Figure 18: Wheel path wearing in all treatments.

2nd Year Evaluation

A site visit was completed on April 10, 2008 after the site received a second year of winter maintenance. The Slurry Seal section remained on approximately 40% of the lane and the treatment along the sides of crackfilled areas continued to wear, Figure 19. The Thin HMA Overlay remained in excellent condition, excluding a few potholes noted just north of the Exit 7 off-ramp, Figure 20. The NovaChip® also was noted to be in excellent condition. Approximately 19 transverse cracks were noted, a majority of which began in the passing lane and did not extend across the full roadway width. This could be attributed to the steep slope decrease from the passing side to the travel side with consideration to the relatively (for the season) high water table; one can conclude that the thermal cracking exhibited on the site was caused by extensive temperature changes including many freeze-thaw cycles and varying temperatures. Five localized depressions were noted within the NovaChip® section in the travel lane at MM 44.5 near the white edge line, Figure 21. This could have been caused by traffic loading and a weakened underlying structure do to climatic conditions listed previously.

Figure 19: Overview of Slurry Seal and the Thin HMA Overlay treatments.

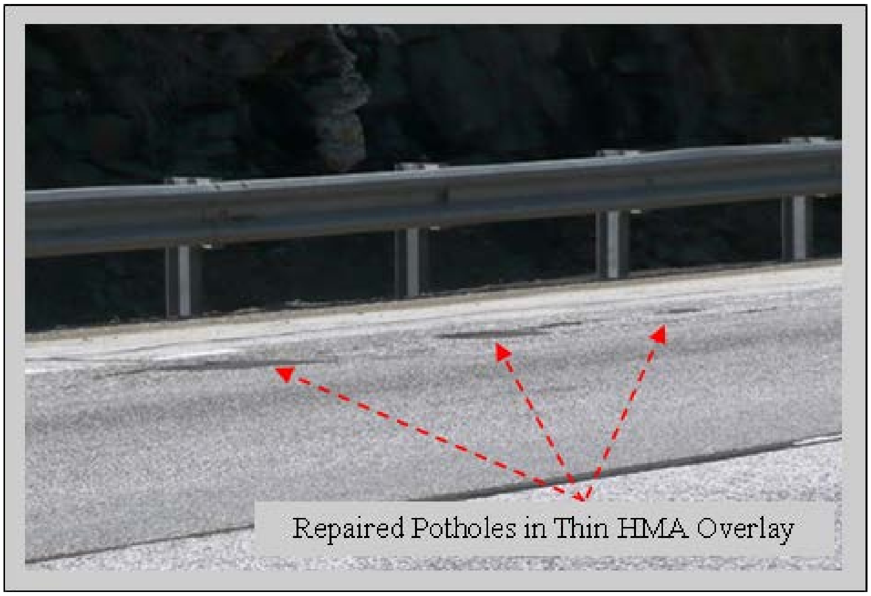

Figure 20: Repaired potholes in Thin HMA Overlay section, Overlay section near Exit 7.

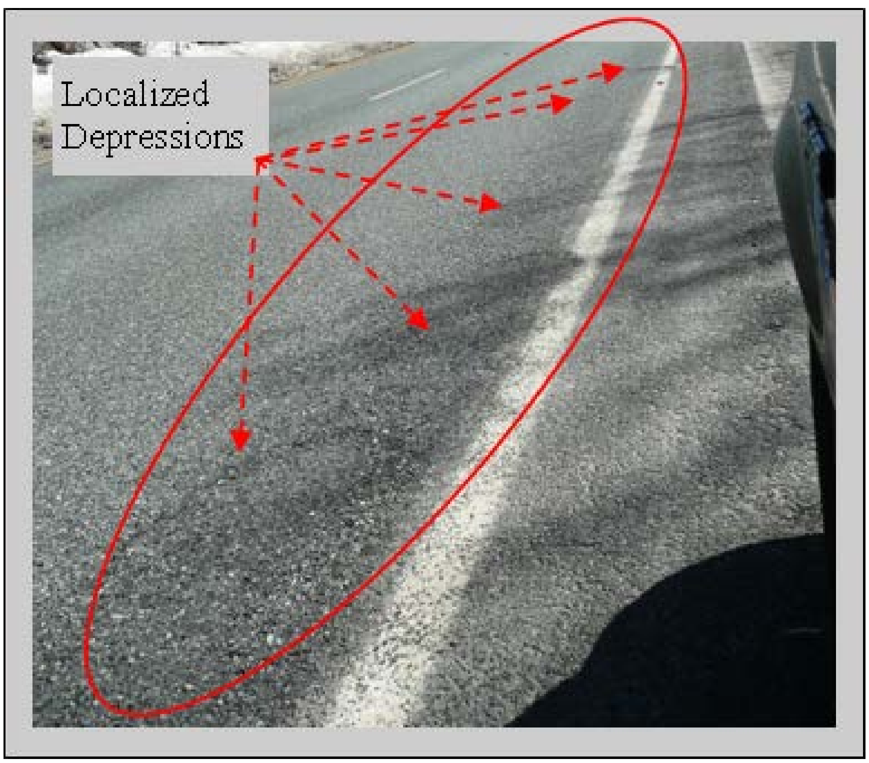

Figure 21: Localized depressions located at MM 44.5 in the travel lane within the NovaChip® section.

3rd Through 6th Year Evaluation

Slurry Seal

Site visits were performed over the next six years, from 2009 to 2014. All of the treatments increased in distresses. The Slurry Seal treatment was estimated to be 5% remaining in 2009, three years after placement. Figure 22 shows the treatment at the 2010 site visit. VTrans Maintenance and Operations Bureau repaved the Slurry Seal section in 2012, through a maintenance paving contract due to poor surface conditions and excessive rutting, subsequently ending this portion of the evaluation.

Figure 22: Remaining Slurry Seal Treatment in 2010.

Thin HMA Overlay

Cracking, both transverse and load related longitudinal cracking, was noted in the Thin HMA Overlay section beginning in 2009 and progressing throughout the following evaluation years, Figure 20 and Figure 23. The potholes located just north of the Exit 7 ramp first observed in 2008 continued to need repair maintenance, including filling and patching. A year after the Slurry Seal section was repaired in 2013, it required paving as well due to safety concerns associated with excessive rutting creating hydroplaning situations, Figure 24. Figure 25 shows what presumably is the underlying pavement course where stripping and raveling was evident.

Figure 23: Potholes near Exit 7 in 2013.

Figure 24: Thin HMA Overlay section overview, just prior to paving in 2013.

Figure 25: Pavement wear.

<u>NovaChip®</u>

Transverse cracking persisted in the NovaChip® section over the evaluation time. In 2009, there were approximately 132 transverse cracks, either partial or full lane width in length were noted in this section. These increased at each annual site visit and the total number was not continued to be recorded. The localized depressions did not appear to get much worse in the six years following first observing them in 2008. This condition suggests that the depression were principally a construction rather than wear phenomenon. The final site visit was conducted in the spring of 2014 prior to the rehabilitation project, IM 089-1 (61) that spanned the length of the entire three previously treated areas. There were several transverse cracks noted, most full lane width. Figure 26 is an overview of the treatment at this visit.

Figure 26: NovaChip® overview in 2014.

COST ANALYSIS

In the current environment of balancing rapidly deteriorating infrastructure with limited funding, many states have shifted their approach of managing the serviceability and condition of their pavement networks. Historically many states practiced the "worst-first" treatment approach for the entire network. This approach, although tempting is not achievable with scarce funding sources. When rehabilitating pavements that haven fallen to the "Very Poor" range the costs can range from $500,000 to $5,000,000 depending on what needs to be completed to bring the structure back into satisfactory serviceability condition (*18*).

Over the past few years, many states including Vermont have targeted their funding proactively between rehabilitating the "very poor" highways and utilizing preventative maintenance strategies to extend the remaining service life of other roadways that are in better condition to improve the overall road network (*18*).

Often times paving treatment costs can vary dependent upon the location of the project and production plant, material availability and associated costs, equipment required, and familiarity with the application process. Sometimes if a treatment is new to a contractor, the price can be more initially than after they have gained experience with it. This is an important factor to note when determining the life cycle costs of a specific treatment.

For this evaluation, the total construction cost was $1,149,415.48, shown in Table 4. The Thin HMA Overlay was the most expensive treatment, totaling $144,460.80 cost per mile (2 – 12 foot lanes), followed by NovaChip® totaling $126,720.00 and then Slurry Seal equaling $83,635.20.

Table 4: Williamstown-Montpelier Treatment Cost.

Treatment Type	Total Cost	Cost per SQ FT	Cost per Mile (2 - 12 FT Lanes)
NovaChip®	$610,302.04	$1.00	$126,720.00
Slurry Seal	$196,424.52	$0.66	$83,635.20
Thin HMA Overlay	$342,688.92	$1.14	$144,460.80
Total	**$1,149,415.48**		

Since this project was constructed in 2006 there have been 39 PMT projects constructed to date. Many times in Vermont, PMT projects are advertised using an alternate bid practice where perspective contractors are required to bid the project including costs for all specified treatment types. The treatments selected are those that are deemed satisfactory by the Pavement Design Unit for placement at the location. The purpose of including alternates is to keep costs lower, capitalizing on available funding.

Table 5 summarizes the PMT used since 2006. The three treatments at the top are the types that were used in this evaluation. Paver Placed Surface Treatments have been constructed the most by far, totaling 24 projects, equaling a total of $59,750,972.00. Based on this study the treatment extended the underlying pavement structure by 8 years, equating to $18,118 per year. Had the pavement received a rehabilitative approach, that annual cost could have been more than tripled that amount, equaling anywhere from $60,000 to $600,000 over the life the treatment.

Table 5 Cost Breakdown of PMT to Date.

Treatment	# of Projects Since 2006	# of Lane Miles Since 2006	Total Spent	Average Cost per SQ. FT.	Average Cost per Mile (2 - 12 FT lanes)	Performance (Years)	Cost per Year of Life Extension
Paver Placed Surface Treatment, Type C	24	861	$59,750,972	$1.14	$144,945	8	$18,118
Mill and Fill	1	22	$3,395,693	$1.23	$156,138	7	$22,305
Micro Surfacing	6	144	$9,499,851	$1.09	$138,659	1	$138,659
9.5 mm Highly Polymer Modified Thin HMA Overlay with 0% RAP	1	2	$265,138	$1.79	$227,261		
9.5 mm Highly Polymer Modified Thin HMA Overlay with 25% RAP	1	2	$234,063	$1.58	$200,625		
6.3 mm Polymer Modified Bituminous Concrete Pavement	2	26	$2,267,128	$1.17	$147,956		
Chip Seal	2	15	$771,978	$0.70	$88,556		
Hot-in-Place Recycle	2	25	$950,767	$0.57	$71,607		
Total	39	1096	$77,135,590				

*Based on lane width estimates of 12 ft.

SUMMARY AND RECOMMENDATIONS

Historically state DOTs have used a purely rehabilitative approach to address infrastructure deficiencies, however with stretched budgets and rapidly deteriorating roadways, they have recognized the need to shift their approach of how to manage their pavement infrastructure assets by balancing the rehabilitative and maintenance projects to improve and extend the life of the overall pavement network. FHWA as well as the US Congress have further recognized the importance of PMTs and have encouraged State DOTs to include them in their pavement asset management plans.

Preventative maintenance treatments (PMTs) are intended to arrest minor deterioration, retard progressive failures, and reduce the need for corrective maintenance, have the potential to both improve quality and reduce expenditures. The life cycle and associated cost-effectiveness of PMTs may vary significantly based upon the selected treatment, functional classification, traffic demand, condition of the roadway prior to application, constructability and environmental conditions (*3*).

The timing of placing PMT is essential to the success of the treatment. If placed too soon or too late its' overall benefit decreases greatly. The Long-Term Pavement Performance (LTPP) program along with other studies have shown that the proper execution of a pavement preservation program using various PMTs will increase the life-cycle of certain pavements by extending the time until a corrective or reactive rehabilitation is needed. This not only results in overall cost savings, but increases user support based on better and longer pavement condition (*4*).

The intent of this research initiative was to evaluate the constructability, performance and cost effectiveness of

1) NovaChip®, a paver placed surface treatment;
2) Slurry Seal, a microsurfacing Type I treatment; and
3) Thin hot mix asphalt (HMA) overlay, a standard mill and fill treatment.

The study included examining the condition of the preexisting roadway surface, construction details, performance including cracking, roughness, and rutting indices, and observations over the course of the evaluation.

The Slurry Seal section deteriorated rapidly. Within a year and half of the application, the treatment had essentially worn down completely, exposing the underlying preexisting pavement. Values recorded over the period of this study do not relate directly to the Slurry Seal treatment. These values should be considered an extension of the pavement that was in place when the treatment was applied. Observed conditions during the construction preclude a reasonable assessment of this technology.

In terms of transverse and structural cracking and IRI, the NovaChip® Paver Placed Surface Treatment and Thin HMA Overlay performed equally and exhibited consistent pavement condition indices over the length of the evaluation. Both treatments ended with "Good" PCI values, ranging from 95-99 for transverse and structural cracking distresses. For IRI both treatments were in the fair range with indices from 81 to 83. The Rut Index is where the treatments differed in the evaluation. Where NovaChip® remained consistent in this category like the other distress categories, concluding the study with an index of 94.45 at the end of 8 years, the Thin HMA Overlay steadily decreased and was 23.08 at the end of 7 years.

NovaChip® outperformed the Thin HMA Overlay and Slurry Seal treatments. At the end of 8 years, NovaChip® in the passing lane had an overall PCI average of 88.95 and 75.26 in the travel lane. The Thin HMA averaged 74.98 overall after 7 years, followed by Slurry Seal averaging 60.02 after just 1 year after application.

IMPLEMENTATION STRATEGY

Since this evaluation, 39 PMT projects have been constructed in an effort to prolong the life of our structural pavement assets. Some lessons have been learned regarding where and when to place different treatments and the program is now an integral part of the Pavement Management System. These projects often are bid with alternate options allowing VTrans to get the most of the funding resources. Paver Placed Surface Treatments are applied most frequently, totaling 24 of the 39 projects. There have been 6 microsurfacing (Slurry Seal type) however, this treatment has not continued to perform well at the locations across the state and have in some cases needed repair as early as 3 years after construction. More details regarding this issue will be described in a future report in conjunction with the SPR 713 research initiative. Other experimental treatments include those listed in Table 5. These treatments are monitored and so far have been reporting to be successful to date.

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