BITUMINOUS OVERLAY STRATEGIES FOR PREVENTIVE MAINTENANCE ON PENNSYLVANIA INTERSTATE ROADWAYS

by

Shreya Gopal

B.E. Transportation Engineering,

B.M.S. College of Engineering, VTU, Belgaum, Karnataka, India, 2006

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SWANSON SCHOOL OF ENGINEERING

This thesis was presented

by

Shreya Gopal

It was defended on

April 5, 2010

and approved by

Dr.Amir Koubaa, Academic Coordinator, Department of Civil and Environmental Engineering

Dr. J.S. Lin, Associate Professor, Department of Civil and Environmental Engineering

Dr. Maher Murad, Associate Professor, Department of Civil Engineering Technology

David Peshkin, Vice President, Applied Pavement Technology, Inc.

Thesis Advisor: Dr. Amir Koubaa, Academic Co-ordinator,

Department of Civil and Environmental Engineering

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Shreya Gopal, MS

University of Pittsburgh, 2010

In 2008, Penn DOT initiated a two-stage process to identify appropriate bituminous overlay strategies for interstate pavements. The first stage consisted of a comprehensive review of the preventive maintenance practices and best practices at a national level and the second stage involved the identification of practices within each district in Pennsylvania. Identification of the most effective practices, both locally and nationally, can be used as a lead-in to the implementation of a strategy for the use of preventive maintenance procedures on interstate and interstate look-alike pavements in Pennsylvania. The research approach involved an extensive literature review to identify the preventive maintenance practices, and outline the key elements or factors influencing these practices. The most common techniques observed are thin hot mix asphalt overlays, microsurfacing, chip sealing, crack seal, and polymer modified hot mix asphalt overlay. The factors influencing these techniques include climate, traffic conditions, relevant geography, life cycle costs, pavement performance indices, application temperature, service life, pavement distress, and pavement age. The literature review, state survey, and district survey results were used to generate a list of best preventive maintenance practices applicable in Pennsylvania. The identified techniques were also compared to findings from Long Term Pavement Performance data. The study concludes the best practices for preventive maintenance of Pennsylvania interstate pavements. The selected identified best practices can be implemented on experimental test sites to validate the findings of the study.

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1.0 INTRODUCTION

This study was conducted to identify the effective bituminous strategies for preventive maintenance on high traffic volume roadways as a part of a research project for the Pennsylvania Department of Transportation (Penn DOT). High traffic volume roadways over a period of time are subject to damage due to factors such as climate, traffic, material properties, and construction materials. The distressed pavement exhibits different forms of deterioration such as cracking, rutting, potholes, corrugation, patching, and bleeding. These influence the condition of the pavement and the treatment selected to restore the properties of the section.

1.1 BACKGROUND

American Association of State Highway and Transportation Officials *(AASHTO*, *1993)* defines preventive maintenance of as “the 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 (without substantially increasing structural capacity).”

Preventive maintenance is usually applied to pavements in good condition to extend their service life by applying cost-effective treatments to the surface or near surface. These techniques include asphalt cape seal, crack seal, chip seal, slurry seal, fog seal, open graded friction course, microsurfacing, polymer modified HMA, and ultra thin HMA overlays.

Maintenance on high traffic volume roadways presents its own particular challenges, and there are many different types of treatments that are used on these pavements, referred to by Penn DOT as interstate pavements and interstate "look-alikes." The restoration of pavement quality is often associated with a variety of conditions and factors. Preventive maintenance treatment on a bituminous pavement is typically initiated when the pavement surface exhibits forms of visible pavement distress, deterioration in the pavement serviceability, and reduction in ride quality. Traffic, pavement condition, distresses exhibited, temperature, and geographical location of the pavement also influence the preventive maintenance treatment rendered *(Peshkin et al. 2009)*.

The identification of an effective preventive maintenance strategy involves the analysis of conditions under which a particular technique is effective, and the pavement performance results that are obtained from the implementation of that method. This study provides an overview of the various methods of preventive maintenance treatments applied in different states and amongst the various districts within Pennsylvania. Each method performs differently depending on the location of application. The practices of state highway agencies around Pennsylvania were analyzed to determine the effective methods implemented to improve the pavement performance. The results were then used to offer recommendations of treatments that are applicable to Pennsylvania.

1.2 STATEMENT OF THE PROBLEM

Bituminous surfaced pavements in Pennsylvania deteriorate as a result of a variety of factors. Distress conditions like cracking, potholes, weathering and raveling, rutting, and bleeding are some indicators of the pavement condition. The strategy of preventive maintenance for pavements plays a key role in improving the serviceability of the pavement. The identification of an effective treatment is the first step to the development of this strategy.

Bituminous pavements are subjected to a number of conditions such as traffic, temperature variations, and climatic conditions which influence the quality of the pavement and, with time, lead to deterioration. However, there are a combination of methods and techniques to apply preventive maintenance treatment to the deteriorated pavement. This study focuses on determining the best practices of preventive maintenance for typical conditions of the pavement. The best preventive maintenance practice depends not only on the range of factors that influence the effectiveness of a treatment but also on the applicability of that treatment in Pennsylvania.

1.3 STUDY OBJECTIVES

The objectives of this study are to:

- identify various preventive maintenance techniques
- highlight the different conditions and practices implemented in different states
- identify preventive maintenance practices in Penn DOT districts
- identify list the detailed conditions for preventive maintenance practices
- And prepare a list of available effective treatments in Pennsylvania

The literature review, surrounding state level surveys, Pennsylvania district surveys, and Long Term Pavement Performance results were used to address the objectives for this study. The literature review was conducted to identify the various preventive maintenance techniques. The state survey and Penn DOT district surveys were performed to identify the preventive maintenance practices and the conditions of implementation of the treatments. Long Term Pavement Performance data was used to obtain the conditions under which these treatments are implemented by the various state agencies. This thesis provides a summary of best practices, conditions, and factors under which the treatments are used in the various states.

Preventive maintenance guidelines can later be developed by the state agencies provides an effective strategy for preventive maintenance of bituminous surfaced high traffic volume roadways for the different states.

1.4 RESEARCH APPROACH

The research approach for this study consists of the following tasks:

Task 1: Literature Review

An extensive literature review was conducted to determine the current practices of preventive maintenance in different states. The literature review was conducted using the University of Pittsburgh library system. Publications and research papers related to the study were located using the NTIS (National Technical Information Service), TRIS (Transportation Research Information Services) online, online databases (e.g., compendex and inspec). The information collected was organized based on the treatment type, treatment design consideration, and expected life. The literature review was based on various treatment types and the factors influencing these treatments, such as; pavement condition, traffic condition, and geographical location. The review process consisted of two activities:

1. Collection of information with respect to the treatment types, pavement distress, performance rating, serviceability, traffic classification, and climatic conditions.
2. Develop a comprehensive list of all the available treatments and factors influencing them.

Task 2: Surrounding state survey

The effective preventive maintenance practices used by state highway agencies were identified either with conditions similar to Pennsylvania or neighboring Pennsylvania. A state survey was sent out to 10 State Highway agencies, including New York, Ohio, Minnesota, Michigan, Virginia, West Virginia, Maryland, Texas, New Jersey, and Indiana. The five states that responded to the survey questionnaire are New York, Ohio, Minnesota, Michigan, and Virginia. The questionnaire aimed to understand the preventive maintenance treatments, conditions of treatments, and the best practices relevant to the state highway agency.

Task 3: District wide survey

The Pennsylvania district level survey was conducted to determine the effective preventive maintenance practices. A survey questionnaire was developed to collect information about the preventive maintenance conditions such as application temperature, traffic conditions, distress condition, distress severity, expected service life, and serviceability rating of the pavement for applying a particular treatment. The questionnaire included a district level rating of the preventive treatments based on the effectiveness and frequency of their application. The survey aimed at identifying the maintenance techniques such as, the thickness of the overlay or treatment. The districts were also asked to enumerate the pre-overlay repair required for different treatments.

The responses from the survey were used to analyze the most common preventive maintenance treatment, the conditions of application, and compile a list of the available treatments. The list obtained was compared against the Pennsylvania Department of Transportation, Publication 242 to conclude on the applicability of the identified treatments.

The Long Term Pavement Performance Data was used to extract information for the same states that responded to the survey questionnaire. A comparison was performed between the LTPP data for the states and the information obtained from the survey and literature review. The information highlighted the conditions that are implemented on the different Strategic Highway Research Program (SHRP) roadways in different states under various conditions. The results of the LTPP data were used to validate the results of the literature review, state survey, and district level survey.

Task 4: Analysis of Results

A list of preventive maintenance treatments was formed from the literature review, and surveys were compared to present the most effective treatments on Pennsylvania interstate roadways. The results of the review and the survey were summarized according to the conditions affecting the preventive maintenance treatments. Each treatment was analyzed based on the findings of the review and survey to summarize the conditions, application treatment, and effectiveness of the treatment. The detailed summary for these treatments were used to compare the best practices of the states and make recommendations for preventive maintenance on Pennsylvania interstate pavements.

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

The objective of the literature review was to identify preventive maintenance practices implemented by different state agencies. The literature search was conducted using *Transportation Research Information Services* (TRIS) online and University of Pittsburgh library systems. The results from the literature review can be divided into three categories of information: Treatment type, Treatment Design Consideration and Treatment Expected Life. The type and application method of a treatment depends on the geographical location of the pavement and specific guidelines.

A list of common preventive maintenance treatments used by different state agencies was obtained. The description of the practices that are implemented for treating the various distress conditions observed on the pavement are summarized in this chapter. A treatment can be classified as restoration, resurfacing or reconstruction.

Restoration can be defined as the rehabilitation of the pavement surface by renewing the properties of the surface. Resurfacing refers to the replacement of the surface layer of the deteriorated pavement. Reconstruction of the pavement is the rebuilding of the entire depth of the pavement.

The application of a resurfacing treatment can be further classified as Pre-treatment, Preventive Maintenance and Rehabilitation. Pre-treatment is defined as the application of a treatment before the placement of a preventive maintenance treatment (*FHWA, 2003*). AASHTO (1993) defines preventive maintenance as "the 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 (without substantially increasing structural capacity)".AASHTO (1993) also defines rehabilitation as the process of removing and recycling the old pavement to prepare a new pavement and surface. The list of most widely used pretreatments, preventive maintenance and rehabilitation techniques are as follows:

<u>Pre-treatment repair</u>

- Crack Seal

<u>Preventive Maintenance</u>

- Single Course Chip Seal
- Quick Set Slurry / Slurry Seal
- Cape Seal
- Fog Seal
- Heat Scarification of HMA Pavement
- Microsurfacing
- Paver Placed Surface Treatment (Novachip)
- Thin Hot Mix Asphalt Overlay
- Open Graded Friction Course
- 6.3mm Polymer modified HMA

Rehabilitation

- Cold In-place Recycling
- Cold Mix Recycling
- Hot Surface Recycling

2.1.1 Pre-treatment Repair

2.1.1.1 Crack Seal

AASHTO 1993 Design Guide describes crack seal as a localized treatment method used to prevent water and debris from entering a crack, which might include routing to clean the entire crack and to create a reservoir to hold the sealant. It is only effective for a few years and must be repeated. However, this treatment is very effective at prolonging the pavement life. Figure 1 represents crack sealing being performed.

Figure 1. Crack sealing being performed (www.chipseal.com)

2.1.2 Preventive Maintenance Treatment

The various preventive maintenance treatments which are used to maintain an asphalt pavement are defined in this section.

2.1.2.1 Single Course Chip Seal

AASHTO 1993 describes Single Course Chip Seal as a sequential application of asphalt and stone chips which can be made either singly or repetitive layers to build up a structure approaching 1 inch thick, sometimes called armor coating. This treatment is also used on low-volume roads. In case of repetitive layers the treatment is also called as double course chip seal.

According to the Federal Highway Administration publication NCHRP Synthesis 342, a chip seal (also called a "seal coat") is essentially a single layer of asphalt binder that is covered by embedded aggregate (one stone thick), with its primary purpose being to seal the fine cracks in the underlying pavement's surface and prevent water intrusion into the base and subgrade. The texture of a chip seal is shown in Figure 2. The aggregate's purpose is to protect the asphalt layer from damage and to develop a macrotexture that results in a skid-resistant surface for vehicles *(Gransberg et al., 2005)*.

Figure 2. Chip Seal (www.chipseal.com)

2.1.2.2 Quick Set Slurry / Slurry Seal

AASHTO (1993) also defines slurry seal application as a diluted emulsion mixed with sand sized aggregate in a special mixer. This slurry is then squeegeed onto the pavement surface. The thickness of the slurry seal is generally less than 3/8 inches. Figure 3 shows laying of slurry seal on the pavement surface.

Figure 3. Slurry Seal being laid on the pavement surface (www.unitedpavinginc.com/services.php)

2.1.2.3 Cape Seal

AASHTO (1993) defines cape seal as a combination of both a slurry seal and either or a microsurfacing on top. The Cape seal, if constructed properly, provides a smooth, dense surface, one having good skid resistance and a relatively long service life. Cape seal, in addition, provides a durable and an impervious surface.

Cape seal is a combination of both slurry seal and chip seal. The advantage of the cape seal is that a thicker, more durable surface is obtained, and it can be used on higher volume roads. The cape seal typically results in a smoother pavement with a more pleasing appearance, and can provide added skid resistance *(NYSDOT, 2005).* Figure 4 shows the application of cape seal.

Figure 4. Application of slurry seal before placing chips (www.cityofsalem.net)

2.1.2.4 Fog Seal

A fog seal is an application of dilute emulsion with no aggregate. It seals the surface and provides a small amount of rejuvenation. It also provides a very distinct delineation between mainline pavement and the shoulder, where they are primarily used, on high-volume roads *(AASHTO, 1993).* Figure 5 shows the application of fog seal.

Figure 5. Fog Seal (mpw.nashville.gov)

2.1.2.5 Heat Scarification of HMA

AASHTO (1993) defines heat scarification of HMA as a technique to prepare the surface of an existing asphalt pavement prior to a preventive maintenance overlay. It is a multi-steps process, in which the existing pavement is heated and scarified. The depth of scarification is usually between 0.5 and 0.75 inches. After adding the asphalt recycling agent, the mixture is reshaped, compacted, and replaced over the recycled pavement. The heat scarification process is shown in Figure 6.

Figure 6. Heat Scarification in progress (www.fhwa.dot.gov/pavement/recycling/98042/09.cfm)

2.1.2.6 Microsurfacing

The Asphalt Pavement Preservation Guide (2006), defines microsurfacing as, "A mixture of polymer modified asphalt emulsion crushed dense graded aggregate, mineral filler, additives, and water. Microsurfacing provides thin resurfacing of 0.3 to 0.75 inches to the pavement and returns traffic use in one hour under average conditions. Materials selection and mixture design make it possible for microsurfacing to be applied in multiple lifts and provide minor re-profiling. The product can fill wheel ruts up to 1.5 inches in depth in one pass and produces high surface friction values. Microsurfacing is suitable for use on limited access, high-speed highways as well as residential streets, arterials and roadways".

Figure 7. Microsurfacing (www.dotd.louisiana.gov)

2.1.2.7 Paver Placed Surface Treatment

According to the Asphalt preservation guide, paver placed surface treatment can be described as a high-performance surface course for preventive maintenance on new construction. It consists of application of polymer modified asphalt emulsion followed by an ultra thin gap-graded HMA overlay. Surface treatments are referred by different names in different states such as; Novachip is the name used by ODOT. Figure 8 represents the treatment. The surface treatment places a thin about 0.75 inch, gap graded coarse aggregate hot mix asphalt over a Novabond membrane (polymer modified asphalt emulsion seal coat).

Figure 8. Cracks sealed after surface treatment (www.tampapaving.net)

2.1.2.8 Thin Hot Mix Asphalt Overlays

The Asphalt pavement preservation guide (2006) defines thin overlays is a thin hot mix asphalt concrete applied at a thickness less than 2 inches. Thin HMA overlays can also be defined as an appropriate top course mixture with specific mix type and compaction requirements. The thickness of the treatment depends on the design traffic loading of the pavement.

Figure 9. Microsurfacing layer (www.fhwa.gov)

2.1.2.9 Open Graded Friction Courses

AASHTO (1993) defines open graded friction course as an application of asphalt resurfacing in which the aggregates drain water off the pavement surface by providing an open, porous structure in the mixture. The rapid removal of water reduces the potential for hydroplaning and, hence, wet weather accidents. These applications are often called plant mix seals or popcorn mixes.

Figure 10. Sample of Open Graded friction course (www.wsdot.wa.gov)

2.1.2.10 Polymer Modified HMA

Polymer modified HMA is a top course mixture consisting of a 6.3 mm polymer modified HMA overlay *(Asphalt Pavement Preservation Guide, 2006).*

2.1.3 Rehabilitation

Rehabilitation is essentially performed when a pavement surface is non-serviceable and requires immediate attention. Pavement rehabilitation consists of "structural enhancements that extend the service life of an existing pavement and/or improve its load carrying capacity. Rehabilitation techniques include restoration treatments and structural overlays." *(www.fhwa.gov)*

2.1.3.1 Cold In – Place Recycling (CIR)

The Asphalt Pavement Preservation Guide (2006) states that CIR can be defined as, a reliable, engineered process for partial depth cold recycling to improve the serviceability of severely distressed asphalt pavements having structurally sound bases and good drainage. The recycled pavement is sealed or overlaid as needed.

Figure 11. Cold In-place Recycling (www.fhwa.gov)

2.1.3.2 Cold Mix Recycling

Cold-mix recycling (CMR) is a practice in which reclaimed asphalt pavement (RAP) materials are combined with a new recycling agent and/or an aggregate to produce cold-mix paving materials *(Asphalt Pavement Preservation Guide, 2006)*. This process can be carried out either in situ or at a mixing plant and is not performed to a depth greater than 25 to 50 mm. The resulting cold-mix material is usually used as a base course, on which a protective asphalt surface layer is placed. In general, CMR is appropriate for low-volume asphalt roads that are severely cracked and broken, highly rutted, or very rough. This practice is not recommended for roads with obvious soil foundation problems or those with asphalt mixture problems which cannot be adequately corrected with CMR *(NYSDOT, 2005)*.

2.1.3.3 Hot Mix Recycling

The Asphalt Pavement Preservation Guide (2006) defines Hot Mix Recycling as, a reliable, engineered process for partial depth hot recycling to improve the serviceability of severely distressed asphalt pavements having structurally sound bases and good drainage. The emulsion includes rejuvenator oils for bringing the aged asphalt back to life and polymer modified asphalt for added adhesion, elasticity, temperature resistance and durability.

2.2 STATE DOT PRACTICES

The main objective of the literature review was to enumerate best practices and preventive maintenance techniques implemented by different state agencies. This section summarizes the factors, conditions, and requirements of the practices implemented in each of the different states.

2.2.1 California State Department of Transportation (Caltrans)

Flexible Pavement Rehabilitation Manual (2001) reported that pavement preservation is the most cost effective approach to increase the service life of a pavement. The pavement preservation techniques include microsurfacing, slurry seals, chip seals, thin and ultrathin overlays. A more common method of pre-overlay repair used by Caltrans is crack and joint sealing.

2.2.1.1 Pre-Treatment Repair

(a) Crack Seal:

Kuennen (2005) reported that crack filling and sealing is its first line of defense in roadway maintenance. Caltrans urges that cracks ¼ inch or wider be filled or sealed before rainy seasons or before the application of maintenance surface treatments such as fog seals, sand seals, slurry seals, chip seals or maintenance overlays.

2.2.1.2 Preventive Maintenance Treatment

(a) Chip Seal:

One of the methods used for rehabilitation in San Diego County was the use of chip seal with either latex modified emulsion over fabric or ground rubber modified paving asphalt binder. Chip sealing with ground rubber modified paving asphalt binder performed well on roads that did not have wide surface cracks. If they were present, crack sealing would also be needed. However, chip seal with latex modified emulsion over fabric eliminated the need for crack sealing, regardless of the width of the surface crack. The pavement surface exhibits a service life of about 18 years as the fabric is still intact and the underlying base is in good condition. Fabric placement is not recommended in areas with steep grades *(Kuennen, 2005)*.

Kuennen (2005) also reported that chip seal provides considerable amount of returns and improve the condition of the pavement surface. The application of chip seal increases the resistance of a pavement surface to the various environmental affecting the pavement texture and lead to cracking and other forms of deterioration. Caltrans has experienced improved services with the use of chip seals. Since chip seals can be incorporated to have a higher quality of aggregate in it, owing to the lowering of other costs, the durability of this treatment is much better. Thus, Caltrans concluded that with an appropriate design the chip seal is an effective pavement preservation tool.

(b) Slurry Seal:

The slurry seal is applied at a rate of about 9.8 kg/m^2 about 48 hours. The treatment life was observed to be about 3 to 5 years *(Solaimanian, 1998).*

(c) Cape Seal:

Although the California Department of Transportation (Caltrans, 2001) has not been experimenting with Cape seal, it has made extensive use of chip seals with emulsions and polymer-modified and tire-rubber modified asphalts. Pre-coated 10 mm aggregates are mainly used with tire rubber- modified asphalt. Slurries are also utilized, but not in connection with chip seals. City and county officials within the state have, however, rehabilitated roads using Cape seal techniques, primarily to provide a skid-resistant surface and a good appearance (important in terms of favorable public perceptions). The constructed Cape seals have been performing very well and have been effective in preventing reflective cracking. The life expectancy of the constructed Cape seals is about 10 years (roughly equivalent to 50 mm of hot mix asphalt). The cost is about 35 percent less than that for a 50 mm HMAC overlay *(Solaimanian, 1998)*.

(d) Thin and Ultra thin Overlays:

Kuennen (2005) reported that thin HMA overlays provide a like-new surface, prolong pavement structure life, and make a pavement stronger for only an incrementally higher expenditure than competing surface treatments like chip seals or slurry surfacing. He also reported that for many roads and streets, the best preventive maintenance strategy may be a thin HMA overlay. Thin overlays varying between 0.5 to 1.5 inches combine the best attributes of HMA's strength and smoothness with low cost. Other benefits include HMA's trademark quiet pavement, smooth ride, and aesthetically the brand-new road look.

In 2001, Caltrans initiated the development of the Maintenance Technical Advisory Guide (MTAG) for flexible pavements, treatments and service life. The MTAG summarizes the treatment delay costs based on the various rating parameters and their service life, pavement condition index (PCI) and average life expectancy. The estimates were obtained based on the placement of treatment on existing pavements with three PCI values. Where the PCI is the pavement condition index based on the surface condition, for a good surface, the PCI is 80, fair pavement 60, and 40 for a poor surface condition. The data from the MTAG is as shown Table 1 and Table 2 *(Gardiner et al., 2009)*.

Table 1. Influence of existing pavement condition on anticipated treatment life

Treatment	Good Condition (PCI = 80)	Fair Condition (PCI = 60)	Poor Condition (PCI = 40)
Spray Seals	3 to 5	1 to 3	1 to 2
Chip Seals	7 to 10	3 to 5	1 to 3
Slurry Seals	7 to 10	3 to 5	1 to 3
Microsurfacing	8 to 12	5 to 7	2 to 4
Thin Lifts	10 to 12	5 to 7	2 to 4

Table 2. Equivalent annual cost for pavement preservation treatments as a function of the existing pavement condition

Treatment	**Average Cost for Medium Size Projects ($) per sy**	**Average Life Expectancy**			**EAC, $/yd^2/year**		
		Good (PCI = 80)	**Fair (PCI = 60)**	**Poor (PCI = 40)**	**Good (PCI = 80)**	**Fair (PCI = 60)**	**Poor (PCI = 40)**
Fog Seal	0.23	4.0	2.0	1.5	0.06	0.12	0.10
Chip Seal	2.5	8.5	4.0	2.0	0.29	0.63	1.25
AR Chip Seal	4.35	8.5	4.0	2.0	0.51	1.09	2.18
Slurry Seal	2.08	8.5	4.0	2.0	0.24	0.52	1.04
Microsurfacing	2.5	10.0	6.0	3.0	0.25	0.42	0.83
Thin Overlays	11	11.0	8.0	3.0	1.00	1.83	3.67

In conclusion to this section, Caltrans literature review indicates that Thin HMA overlays provided considerable extension in service life and can be used as an effective preventive maintenance treatment.

2.2.2 Indiana State Department of Transportation (INDOT)

Labi et al. (2005) reported that Indiana DOT uses crack sealing, chip sealing, and thin HMA overlay for preventive maintenance. The details of the preventive maintenance treatment review are presented in the following paragraphs.

2.2.2.1 Pre-Treatment Repair

(a) Crack seal:

Hand et al. (2000) conducted a comprehensive review of crack and joint sealing method. The review revealed little quantitative evidence is present to prove the cost-effectiveness of joint/crack sealing. However, analysis of Long Term Pavement Performance, Special Pavement Studies - 4 test section data showed that test sections with unsealed joints showed more joint deterioration than sections with sealed joints. Labi et al. (2005) analyzed the cost effectiveness of preventive maintenance strategies rather than treatments and determined that the best option for the pavements studied was crack sealing every 4 years and thin HMA overlay every 8 years.

2.2.2.2 Preventive Maintenance Treatment

(a) Chip Seal:

Labi et al. (2005) reported that Indiana State spends about 10 percent of its pavement maintenance budget for chip sealing which is a widely used rehabilitation technique. Chip sealing is reported to increase the resistance to skidding, oxidation, raveling, spalling, and permeability. This method of preventive maintenance is superior to sand seals but much more expensive. From the comparative analysis and tests on road stretches it was seen that the pavement life was considerably extended with the use of chip sealing. However, chip seal is not considered viable for high range of traffic volume pavements owing to lose chips and relatively short life; however, this system can be used at a traffic volume of 7,500 vehicles by adopting a better construction technique. Chip sealing extends pavement life by 3 to 4 years in Indiana.

(b) Sand Seal:

The study by Labi and Sinha (2004) refers to sand seal as seal coating. Seal coating is a viable option for preventive maintenance of low volume traffic pavements, there is no evident increase in the service life. Labi and Sinha (2004) reported that past research on seal coating effectiveness has generally indicated that both short and long-term benefits are associated with this treatment. They also reported that pavements in relatively poor condition were associated with higher performance jumps but lower reductions in their rates of deterioration. This implies that there are greater benefits in preventive maintenance for good pavements compared to relatively poor pavement when considered over an extended period of time. However, the immediate benefit exhibited by pavements undergoing treatment with a good initial condition is much less. The short term benefits of seal coating, as demonstrated in the Indiana DOT study, translate to increased pavement longevity.

(c) Thin HMA Overlay:

Labi et al. (2005) conducted a comprehensive literature review of the long-term effectiveness of thin overlay treatments for the Indiana DOT using three measures of effectiveness: treatment service life, increase in average pavement condition, and area bounded by the performance curve. It was shown that depending on levels of weather severity, traffic, and route type, the service life of thin overlay treatments is approximately 3 to 13 years when *International Roughness Index* (IRI) is used as the performance indicator, 3 to 14 for rutting, and 3 to 24 for *Pavement Condition Rating* (PCR); the wide range of effectiveness is indicative of the sensitivity caused by traffic loading, weather severity levels, and route type. *Labi et al.* (2005) also reported that increased severity of either weather or traffic effects is sufficient to cause a drastic reduction in the treatment service life and that the effect of increased traffic on service life reduction appears to be greater than the effect of increased weather severity.

Chong and Phang (1988) reported that HMA overlays are extensively used and cost effective. The best option for preventive maintenance was noted to be crack sealing every 4 years and HMA overlay every 8 years. Under the influence of traffic and weather, the service life of thin HMA overlay treatment is between 3 to 13 years when a thickness of 40 mm is used. Hand et al. (2005) concluded that as the thickness of HMA layer increased the amount of fatigue, cracking, and rutting reduced whereas, the longitudinal cracking increased considerably.

Labi et al. (2005) analyzed data from Indiana DOT for pavement performance indicators and the service life of the pavement. The long term efficiency of the thin HMA overlays based on the service life was used to predict the expectancy of the thin HMA overlays. The performance of a pavement can also be represented in terms of the following performance indicators: IRI, PCR, and rutting data.

Irfan et al. (2009) defined a range of service life provided by the pavement based on the threshold vales of the pavement serviceability indices. Table 3 indicates the ranges of service life extension.

Table 3. Predicted service life extension for Serviceability Indices for Minnesota DOT

Serviceability Rating Values	Threshold Values	Service Life
International Roughness Index	125 in/mi	3 to 13 years
Rutting Values	0.35 in	3 to 14 years
Pavement Condition Rating	82 on a scale of 100	3 to 24 years

Irfan et al. (2009) concluded that crack sealing is more of a pre-treatment supplementing a preventive maintenance technique such as chip sealing, and thin HMA overly. While crack sealing is most effective when performed at intervals of 4 years, chip sealing is observed to provide an extension in service life; it is not applicable for high-traffic volume roadways. However, thin HMA overlays are most effective for the conditions in Indiana.

In summary, the most effective practice for preventive maintenance implemented by Indiana DOT is the application of crack seal during the initial phase of pavement deterioration. While chip sealing and seal coating are applicable for low volume roads, thin HMA overlays are used for high traffic volume roadways.

2.2.3 Minnesota State Department of Transportation (MnDOT)

The Minnesota DOT funded the development of a handbook (i.e., *Best Practices Handbook on Asphalt Pavement Maintenance by Johnson, 2000*) to help its engineers in implementing a pavement preservation program effectively. Table 4 summarizes the recommendations of this handbook.

Table 4. Asphalt Maintenance Techniques for Minnesota DOT

Use these techniques only on structurally sound pavements.
Appendix A defines low-, medium-, and high-severity cracking.

Technique	Reasons for Use							Average Treatment Life (years)	Average Unit Cost	Reference Page
	Friction	Raveling	Rutting	Potholes	Cracking					
					Low	Med	High			
Crack treatments										
Crack repair with sealing										
Clean and seal					X	X		3	$0.20/lf	26
Saw and seal								7-10	$1.70/lf	28
Rout and seal					X	X		3	$0.70/lf	30
Crack filling						X	X	2-3	$0.25/lf	32
Full-depth crack repair							X	5	$5.00/lf	34
Surface treatments										
Fog seal		X						1-2	$0.15/sy	38
Seal coat	X	X						3-6	$0.55/sy	40
Double chip seal	X	X						7-10	$1.50/sy	43
Slurry seal	X	X						3-5	$1.50/sy	45
Microsurfacing	X	X	X					5-8	$1.75/sy	47
Thin hot-mix overlay		X	X					5-8	$25/ton	49
Pothole and Patching Repair										
Cold-mix asphalt				X				1	$55/ton[a]	54
Spray injection patching				X				1-3	Not Available[b]	55
Hot-mix asphalt				X			X	3-6	$25/ton[a]	57
Patching w/slurry or microsurfacing material				X			X	1-3	0.85/sy[a]	58

[a] Cost for materials only.
[b] Price varies with conditions.
lf=lineal foot
sy=square yard

2.2.3.1 Pre-Treatment Repair

(a) Crack Seal:

Crack Sealing is recommended for the surface treatment of pavements that exhibit medium to low severity longitudinal or transverse cracking. Cracks that are less than 0.75 inch wide are typically sealed to resist water infiltration into the pavement. MnDOT specifies various recommended applications for crack sealant and fillers like rubberized asphalt, crumb rubber, asphalt emulsion, and asphalt cement. This kind of maintenance is generally applied when the temperatures are moderately cool and provide a service life of about 3 years. Crumb Rubber is the recommended form of crack sealing. Another method of crack sealing can be saw and seal in which case, the newly paved asphalt is sawn to create a reservoir and sealant is filled at a spacing of 40 feet. It provides an anticipated service life of about 10 years *(Asphalt Pavement Maintenance Handbook, MnDOT 2004).*

Crack filling can be adopted when the cracks are observed on serviced pavements with larger gaps. A hot air lance is used to blow the debris and the sealant added to it, this form of preservation extends the service life by a few months to a year. When these cracks are filled with microsurfacing material or rubberized fillers, the life is extended by 2 to 3 years. A standard specification of material used for crack filling is crumb rubber. In case of secondary cracking, full depth repair is performed with milling a trench about 1.5 inches deep and 14.5 inches wide over the crack and placing an HMA into the reservoir. The life expectancy depends on the density of the mix and mix design specifications. In the best case scenario, the full depth repair can perform for up to 5 years *(Asphalt Pavement Maintenance Handbook, MnDOT 2004).*

2.2.3.2 Preventive Maintenance Treatment

(a) Chip Seal:

Chip seal is referred to as seal coating in the MnDOT Best Practices Handbook on Asphalt Pavement Maintenance Seal coating is recommended in moderate temperatures and low rainfall to increase the friction of the surface, providing an expected life of about 3 to 6 years. MnDOT specifies a particular material for the seal coating. It is generally placed when the pavement and air temperatures are about 50 °F in non-freezing conditions. Traffic restrictions are observed hence in warm weather conditions at least 2 hrs of curing is required. The expected life of this seal coats is 3 to 5 years *(Handbook, MnDOT, 2004)*.

(b) Fog Seal:

The Asphalt Maintenance Handbook, (2004) reports that fog Seal is used in the presence of minor oxidation or raveling by application of an emulsion. The technique extends the service life by about 1 to 2 years in case of good pavement condition and is considered inexpensive. MnDOT specifies a spraying temperature of 125 °F to 160 °F and a surface temperature of about 50 °F for the mix.

(c) Microsurfacing:

Microsurfacing can be used when the rut depth exceeds ¾ inches. It provides a skid resistant surface and reduces the infiltration of water, and can be used on a pavement exhibiting excessive oxidation and hardening. Microsurfacing extends the service life of the pavement by about 7 to 10 years *(Handbook, MnDOT, 2004)*.

(d) Thin HMA Overlay:

Thin HMA overlays are mainly used for functional improvements and can either be dense graded, open graded or gap graded. The thickness varies from 0.75 to 1.5 inch. A pavement with a good surface condition, stable base and visible surface distresses such as extreme raveling, longitudinal cracking qualify for this treatment. Milling of the pavement prior to placement of thin HMA overlay is recommended for the sealing of cracks. Tack coats are used during the application of this treatment. The HMA overlay mixes are placed in warm weather and rolled immediately to achieve the required density. The life expectancy of this treatment can be between 5 to 8 years *(Handbook, MnDOT, 2004).*

(e) Other Treatments:

Flexible Slurry System: The flexible slurry system is a mixture of emulsified asphalt, high quality crushed aggregate, and water. Based on the design, it can be used as a leveling course before overlay or as a wear course. A PG 64-22 grade has been used successfully as it enhances the rutting and cracking performance *(Johnson et al., 2007)*. Flexible slurry is constructed using a microsurfacing machine, but is less brittle than a usual micro surface mixture. With respect to being implemented as a surface course, the slurry can take a range of traffic from low AADT to high AADT (less than 200,000); whereas, as a wearing course the amount of traffic has not been predicted yet. The flexible slurry contributes in enhancing the pavement performance and surface conditions and does not provide structural support. This system is placed using a microsurfacing machine, asphalt distributor, and pneumatic tired roller. The mixture can be allowed to consolidate on the surface with low speed traffic. As per the MnROAD research facility, the life expectancy depends on climatic and traffic conditions. However, considerable amount of improvement was seen on rutted pavement sections. This system resembles asphalt seal coat and can be recycled and milled *(Johnson et al., 2007).*

Johnson (2007) also reported that for programming purposes at the network level, a decision tree has been developed for selecting appropriate treatments given site conditions; on the other hand, most agencies empirically base their program on a fixed schedule, such as applying a surface treatment after 5 years in service. Furthermore, although Mn/DOT recognizes life cycle cost and mix design components are more effective measures of a preservation treatment's effectiveness, the construction cost and overlay thickness are more commonly taken into consideration.

Although Minnesota has experimented with the flexible slurry system and has seen considerable success in extending the service life of the pavement, the life expectancy depends on various climatic and traffic factors. While the treatments used include, chip seal, slurry seal, microsurfacing, and thin HMA overlay, MnDOT literature review indicates that the most effective forms of preventive maintenance treatments applied are double layer chip seal, microsurfacing and thin HMA overlay. MnDOT also reports the use of extensive pre-treatments such as crack seal, crack filling and milling for thin HMA overlays *(Olson et al., 2008)*.

2.2.4 Michigan State Department of Transportation (MIDOT)

The Michigan State DOT implements a comprehensive strategy for working on pavement preservation. This strategy is called the "mix of fixes", which adopts a combination of long-term fixes (reconstruction), medium-term fixes (rehabilitation), and short-term fixes (preventive maintenance). The intention of Michigan DOT is to target the pavement surface defects and not the structural deficiency of the pavement. The surface treatments for HMA pavement surface include microsurfacing, slurry seals, crack sealing, 0.75 inch overlays of ultrathin hot mix asphalt, and 1.5 inch HMA overlays. Cold milling and resurfacing with a 1.5 inch HMA were implemented in case of cost effective maintenance for treating curb and gutter pavement. The strategy used is a three tired program for reconstruction of the worst highway, poor highway rehabilitation, and good highway aggressive preventive maintenance. The various service life expectations for the different rehabilitation methods were predicted based on the pavement condition measures. Table 5 summarizes the Extended Service Life Gains for Preventative Maintenance Treatments for the Michigan DOT *(Galehouse, 2003)*.

Cuelho et al. (2006) reported that MIDOT observes an extension of about 3 to 5 years when the pavement surface is restored with a single layer microsurfacing and about 4 to 6 years for a multiple course application.

In conclusion, although preventive maintenance guidelines are under development for MIDOT, the approach used for treatment of flexible pavement surfaces has been to use a combination of treatments to postpone reconstruction or rehabilitation activities by extending the service life of the original pavement.

Table 5. Extended Service Life Gains for Preventive Maintenance Treatments.

Treatment	Pavement Type	Extended Service Life (years)[a]
Over band crack filling	Flexible	Up to 2
	Composite	Up to 2
Crack Sealing	Flexible	Up to 3
	Composite	Up to 3
	Rigid	Up to 3
Single chip seal	Flexible	3 to 6
	Composite	NA[b]
Double chip seal	Flexible	4 to 7
	Composite	3 to 6
Slurry Seal	Flexible	NA[b]
	Composite	NA[a]
Microsurfacing (single course)	Flexible	3 to 5[c]
	Composite	NA[b]
Microsurfacing (multiple course)	Flexible	4 to 5[c]
	Composite	NA[b]
Ultrathin hot-mix asphalt, 0.75-in. (20-mm) overlay	Flexible	3 to 5[c]
	Composite	3 to 5[c]
Hot-mix asphalt, 1.5 in (40-mm) overlay	Flexible	3 to 5[c]
	Composite	3 to 5[c]
Hot-mix asphalt, 1.5 in (40-mm) mill and overlay	Flexible	3 to 5[c]
	Composite	3 to 5[c]
Joint Resealing	Rigid	3 to 5
Spall repair	Rigid	Up to 5
Full-depth concrete repairs	Rigid	3 to 10
Diamond grinding	Rigid	3 to 5[c]
Dowel-bar retrofit	Rigid	2 to 3[c]
Concrete pavement restoration	Rigid	7 to 15[c]

Notes:
a The time range is the expected life-extending benefit given to the pavement, not the anticipated longevity of the treatment.
b Sufficient data are not available to determine life-extending value.
c Additional information is necessary to quantify the extended life more accurately.

2.2.5 Montana State Department of Transportation (MODOT)

The literature review indicates that Montana State DOT uses treatments such as chip seal, cold in-place recycling, microsurfacing, and thin HMA overlays for preventive maintenance. A description of the characteristics of these treatments is represented in the following sections.

2.2.5.1 Preventive Maintenance Treatment

(a) Chip Seal:

Gransberg and James (2005) reported that the Montana used skid resistance and texture depth measurements as an indicator of the pavement performance for chip seal applications. The average service life extension provided by Chip Seals is about 5 years. Geoffroy (1996) reported that a minimum increase in service life of 2 to 4 years was observed in Montana; whereas a maximum of 7 to 8 years was seen by different state agencies.

The analysis of a few Preventive Maintenance Case studies conducted by Baladi et al. (2002), used distress data from Montana DOT. One of the case studies was I-15 completed in 1997. This stretch of highway received a ¾ inch chip seal, with three different materials for crack sealing. The pavement condition was good after 3 years, indicating an extension in the service life of the pavement. Another case study included a stretch of pavement rehabilitated with Chip seal and the pavement was subjected to extreme temperature changes and harsh environment. The average ADT over the pavement was 4,100 with 20.9 percent commercial traffic. This pavement indicated a service life extension of 9 years. Montana DOT also report successfully using chip seal applications on a roadway subjected to extreme temperature chances and harsh environment although its traffic level is relatively low with an ADT of 4100.

(b) Microsurfacing:

Labi et al. (2005) reported that microsurfacing was seen to extend the service life of the pavement by about 5 to 7 years on an average. Microsurfacing treated pavements have benefited by increases in the pavement condition and pavement life extension by at least 3 years.

(c) Thin HMA Overlay:

According to a survey by Geoffroy (1996), the minimum increase in service life was approximately 2 years and a maximum increase of 9 to 10 years was observed. However, the most common expected service life increase was about 7 to 8 years. For thin HMA overlays, it has been observed that maintenance costs can be reduced and is a viable constituent treatment for preservation *(Cuelho et al., 2006).*

Baladi et al., (2002) reported that Montana State Department of Transportation conducted a case study of preventive maintenance consisting of a 1.8 inch asphalt concrete overlay, chip sealing with latex modified asphalt emulsion. The pavement condition was observed to be in good condition after 3 years of treatment.

By comparing the various literatures review results, it was concluded for increased service life considerations and performance, thin HMA overlays followed by chip seal and slurry seal provided maximum benefit for surface treatments or pavement preservation techniques. Based on the results of the extensive survey for preventive maintenance techniques, it was observed that the most trusted method of preservation was crack sealing followed by thin overlays, chip sealing, and microsurfacing respectively *(Cuelho et al., 2006).*

2.2.6 New York State Department of Transportation (NYSDOT)

In accordance with the New York Pavement Design Manual (2005), NYSDOT practices a variety of preventive maintenance techniques such as:

- Single Course Surface Treatment/Chip Seal
- Microsurfacing
- Paver Placed Surface Treatment
- 6.3 mm Polymer modified HMA
- Quick-Set Slurry
- Hot Mix Asphalt, 40 to 50 mm
- Heater Scarification of Hot Mix Asphalt Pavement.

2.2.6.1 Preventive Maintenance Treatment

(a) Chip Seal:

Chip seal application is concentrated to areas where temperature cracking and fatigue need to be restrained. This controls the oxidation of the pavement. Chip sealing has also proved favorable in increasing the resistance of the pavement against raveling and reducing oxidation and weathering of the surface. The thickness of the treatment is about 10 to 15 mm. The expected service life of surface treatment chip seal is about 2 to 4 years. The conditions for application of this treatment are low severity cracking, raveling or rutting. Chip seals are restricted to low volume and less than 10 percent truck traffic and is recommended for two lane roads with less than 2000 AADT. The minimum pavement temperature requirement is 10 degrees Celsius *(NYSDOT, 2005)*.

(b) Heat Scarification:

Heat scarification of HMA pavement is an optional surface preparation technique to rehabilitate the top course of an existing asphalt pavement maintenance overlay. The depth of scarification for an asphalt pavement is about 25 to 50 mm. An asphalt recycling agent is added to the pavement which improves the properties of aged asphalt. It is expected to extend the overlay expected service life by an additional 2 years *(NYSDOT, 2005)*.

(c) Microsurfacing:

Microsurfacing has been applied in two passes and requires a curing period of 1 hour before it is opened to traffic. This technique is known to increase the service life by about 5 to 8 years. The thickness of microsurfacing is approximately 0.4 to 0.8 inches depending on the type of mix and the design application rate. Apart from reducing oxidation and weathering, it corrects minor surface distresses such as raveling. Crack sealing of the pavement should be performed at least 3 months prior to the application of microsurfacing. These overlays are applied in at least two lifts *(NYSDOT, 2005).*

(d) Thin HMA Overlay:

Thin HMA overlay may be any appropriate top course mixture. The specific mix type and compaction requirements will depend on the design traffic loading of the pavement. There are no traffic restrictions for HMA overlays; however, mixture selection is based on traffic loading. The expected service life of paver placed surface treatment is about 5 to 8 years *(NYSDOT, 2005).*

(e) Polymer modified HMA:

The expected service life of polymer modified HMA overlay varies from about 5 to 8 years. The thickness of this HMA is about 0.8 to 1 inch. However, it costs 25percent more than the HMA overlay *(NYSDOT, 2005)*.

(f) Quick Set Slurry:

Quick Set Slurry is effective in sealing the pavement and resisting the deteriorating effects of oxidation and weathering of the surface. The mixture is continuously applied in a single lift and allowed to cure before opening to traffic. The final thickness varies between 0.2 to 0.6 inches and it renders a pavement service life of about 3 to 5 years. This can be followed up by the application of crack sealing after allowing a time period of 3 months. The emulsion is allowed to cure for 2 to 3 hours before opening to traffic. The temperature and traffic considerations remain the same as the Chip Seal *(NYSDOT, 2005)*.

(g) Thick HMA Overlay:

HMA overlays depend on the traffic flow and the mixture selection and compaction requirements. The expected service life of a 1.5 to 2 inch hot mix asphalt overlay is about 5 to 8 years. HMA overlay is restricted to distresses, such as low severity cracking, infrequent corrugations, heaves or raveling. The minimum pavement temperature requirement is about 47°F (*NYSDOT, 2005)*.

(h) Stress-Absorbing Membrane Interlayer (SAMI):

The application of 1 inch SAMI interlayer in combination with thin HMA overlay to the pavement extends the pavement for about 5 to 10 years over a range of cracking and is proved to be cost effective *(Chen et al., 1992)*.

Microsurfacing and thin HMA overlays are found to be effective by NYSDOT and exhibit a maximum service life extension. Other treatments such as SAMI and slurry seals also indicated a reasonable addition in the life of the pavement.

2.2.7 New Jersey State Department of Transportation (NJDOT)

NJDOT mainly describes crack sealing, microsurfacing and thin HMA overlays as effective preventive maintenance techniques for flexible pavements.

2.2.7.1 Pre – Treatment Repair

(a) Crack Seal:

There are various treatments used for AC surfaced roadways. For Example, Crack Filling/Sealing is used to reduce the crack severity and reduce infiltration of water and incompressible materials. Seal Coating is also reported to be used to reduce all distresses following sealing of surface cracks, inhibit raveling, and improve surface friction *(NJDOT, 2001)*.

2.2.7.2 Preventive Maintenance Treatments

(a) Polymer modified HMA:

Asphalt Institute (Peterson et al., 2004) and the National Cooperative Highway Research Program Project 1-38 (NCHRP, 2004) analyzed a perpetual pavement concept. This has been used in the rehabilitation and reconstruction of a portion of Interstate Highway 710 in southern California. This project incorporated the idea of using a “rich” bottom layer in the hopes of improving durability and possibly fatigue behavior. A rut resistant surface layer using a highly polymerized binder was also employed. HMA mixtures were subject to extensive mechanistic testing in hope of producing a long-lasting structure. The practical implications of the practices as seen in New Jersey found that when the pavement is structurally sound, the placement of a thin overlay using a polymer modified binder in the HMA could keep the pavement in an excellent service condition. The typical application thickness of this treatment is about 3 inches. Thus, it drastically reduces the strains in the pavement structure. The rich bottom utilizes higher asphalt contents, typically 0.5 percent above optimum, in order to achieve greater density and resistance to fatigue. Thus, consequential full depth repairs can be eliminated *(Timm et al., 2006).*

(b) Thin HMA Overlay:

Thin HMA overlay, of about 0.5 to 1.5 inches, is used to reduce the patching severity to a low amount and restoration of rideability, and to improve the surface friction. This technique is used to reduce the distress in pavement and strengthen weaker sections of the pavement, and to improve ride quality.

In conclusion, the literature review indicates that thin HMA overlay, polymer modified HMA and microsurfacing are effective preventive maintenance treatments implemented by NJDOT.

2.2.8 Ohio State Department of Transportation (ODOT)

The various preventive maintenance treatments that are implemented in ODOT as listed in the *Ohio State Preventive Maintenance Guidelines* (2001) are Crack Sealing, Chip Seals, Microsurfacing, Polymer Modified AC and Thin Hot mix asphalt overlay.

2.2.8.1 Pre – Treatment Repair

(a) Crack Seal:

Ohio DOT considers crack sealing as an effective method of preventing the infiltration of water, resisting crack deterioration, and preventing erosion of the pavement. Pavement surfaces showing a distress of raveling and excessive branch cracking are considered for higher forms of maintenance such as microsurfacing. This type of maintenance is most effective when the pavement temperatures are cool to cold and extends the life of the pavement by 2 to 3 yrs before reapplication and is not restricted by the amount of traffic *(ODOT Guidelines, 2001).*

(b) Milling:

Milling is one of the pre-overlay repair techniques used for preventive maintenance. *Section 504 of the Pavement Design Procedures for Minor Rehabilitation* (1999) recommends milling of pavement for better interlocking of the existing surface and the new course to prevent rutting and de-bonding. Ohio follows a structural ratio of 2:3 for new asphalt used to old asphalt for any additional overlay placed in excess of 2 inches. This means that for two parts of new asphalt used, three parts of old asphalt is used.

2.2.8.2 Preventive Maintenance Treatment

(a) Chip Seal:

A single layer chip seal application is considered as a maintenance measure on low volume roadways as it eliminates raveling, reduces the infiltration of water, and retards oxidation along with sealing cracks. Prior to chip sealing certain pavement conditions like that of potholes, wheel track cracking, and edge cracking must be rehabilitated. These applications are used on low volume roads with traffic levels less than 2500 ADT or 250 ADTT. It is ideal to place chip seal in warm weather conditions to allow curing of the surfacing and traffic restrictions should be imposed to control the moving away of chips from the pavement surface. The expected service life that chip sealing renders to the pavement is about 5 to 7 years *(ODOT Guidelines, 2001)*.

(b) Microsurfacing:

Microsurfacing can be carried out to reduce ruts, retard raveling, improve surface friction, and remove irregularities. Minor rehabilitation with regards to potholes and excessive cracking is performed prior to the application of microsurfacing. This technique is suitable for all traffic conditions, a double layer can be used for greater ADT of traffic. The only traffic restriction imposed is until curing; early spring is the right time for this kind of application. The expected service life is about 5 to 8 years *(ODOT Guidelines, 2001)*.

(c) Polymer Modified HMA:

Polymer modified HMA is either a 0.6 inch thickness or 0.75 inch minimum thickness. The technique is used to fill cracks and minor surface irregularities to achieve a uniform surface. This method requires air temperatures above 40°F and provides an expected service life of about 7 to 12 years *(ODOT Guidelines, 2001)*.

(d) Thin HMA Overlay:

Thin HMA overlay is one of the most effective methods of rehabilitation that improves ride quality when performed with milling or scratching to achieve a uniform lift. The thickness of the treatment is limited to 2 inches. Major potholes and longitudinal cracking need to be filled before this maintenance strategy is used, although crack sealing is not a recommended pre-overlay repair technique. The service life of the pavement depends on its condition and the rehabilitation rendered to it in terms of minor rehabs before placing a thin HMA. The expected service life of a structurally sound pavement after overlay is around 8 to 12 years *(ODOT Guidelines, 2001).*

Thin overlays on flexible pavements were found to perform better with better pavement conditions. The benefits were directly related to the reduction in rutting and cracking distresses like those of transverse and longitudinal. The survey performed by Chou et al (2008), reported that the cost for thin HMA overlay is about 40 percent of the average amount for minor rehabilitation in case of the priority system and 60 percent for general system. Thus, this system is cost effective for a pavement surface in good condition. Geoffrey (1996) used a questionnaire survey of sixty transportation agencies and published information to summarize the cost-effectiveness experiences of preventive maintenance treatments. According to the survey responses, the typical pavement age at the time of first thin overlay was about 9 to 10 years, and the typical lifespan of a thin overlay was 9 to 10 years and the observed increase in pavement life was 7 to 8 years *(Chou et al., 2008).*

(e) Smooth Seal:

A Smooth Seal as practiced by Ohio DOT is the placement of about ¾ inch to 1 inch polymer modified thin asphalt overlay and aggregate. This method of surfacing increases flexibility, improves adhesion of the mix to the base, and withstands low temperature cracking. Thus, it reduces raveling, cracking, and delamination of the pavement surface. It would ideally be used to treat minor cracking of surfaces, and add to the structural integrity in order to improve pavement draining. Ohio Department of transportation specifies a thin application of smooth seal as stated above for durable HMA overlay. The polymer modified asphalt with an 8 percent binder content specified by Ohio DOT provides durability, whereas, a heavy polymer modified mixture allows for heavy duty applications. Smooth seal has been tested for performance on different routes in Ohio. However, the service life is not predicted for this type of rehabilitation (*Smooth seal Publication by Flexible Pavement, Ohio 2001).*

(f) Other Treatments:

Ohio DOT specifies certain uses of asphalt concrete within its *Flexible Pavement Design Manual Section 400* for preventive maintenance (2008). These techniques are used in accordance with the Pavement Preventive Maintenance Guidelines. A Fine Graded polymer AC is a suggested application for pavements with ADTT less than 1500 and is to be avoided on unaged crack seals. The use of Rubberized Open Graded Asphalt Friction Course is mainly to increase the skid resistance of the pavement surface and in areas where surface drainage is less. ODOT states that this method is effective in reducing hydroplaning, splash and spray, and tire noise *(Ohio DOT Pavement Design Manual, section 400, 2008).*

Hicks et al., (2004) reported that, chip seals are used to treat pavements exhibiting oxidation, raveling, bleeding, minor cracking and reduced friction, except rutting. Ohio DOT limits the use of chip sealing to low volume roads (less than 2500 ADT) with rutting less than 0.12 inch. Cuelho et al., (2006) state that as a general practice, ODOT repairs all the cracks and patches to full-depth within 6 months of chip sealing. Smooth seal and Thin HMA overlay are also effective techniques of preventive maintenance.

2.2.9 Texas State Department of Transportation (TxDOT)

TxDOT lists Crack seal as one of the preventive maintenance techniques as a pre-overlay repair. Hao (2005) reported that among chip seal, slurry seal, and 50 mm overlay, chip seal is the most cost-effective alternative. The various techniques used by TxDOT are explained in this section.

2.2.9.1 Pre – Treatment Repair

(a) Crack Seal:

Hao (2005) reported that joint and crack sealing are considered to be the preventive maintenance method commonly used for HMA pavements in Texas. Sealing operations on HMA pavements address various forms of cracking such as thermal cracking, reflection cracking, block cracking, and alligator cracking. However, crack sealing is believed to be the most effective on transverse thermal and transverse refection cracks. Additionally, sealing individual alligator cracks is generally not cost effective.

(b) Crack Retarding Grid:

One of few other methods that were examined on a stretch of the US 59 included a crack retarding grid, and crumb rubber modified asphalt. The crack retarding grid was placed at a mid depth of 0.5 inch overlay and 4 inches of crumb rubber was placed. Along with this, a Petromat fabric was used. However, the crack retarding grid section proved to be less resistant to traffic. The performance of the petromat fabric underseal was much better *(Hao, 2005).*

2.2.9.2 Preventive Maintenance Treatment

(a) Chip Seal:

Hao (2005) analyzed the preventive maintenance techniques as a result of the SPS-5 experiments. The TxDOT Pavement Maintenance Information System (PMIS) method was used to compute the distress score of the pavement surfaces. The maintenance treatments were scored according to the effect they had on the distress present. The qualification of the scores by Hao et al., 2005 indicated that chip seal was most effective preventive maintenance treatment in Texas.

(b) Cape Seal:

Solaimanian et al. (1998) enumerated that one limitation of chip seal is that of exposing it to traffic 2 to 7 days before the construction of microsurfacing. An important point to consider is that if there are problems with the chip seal, they must be fixed before microsurfacing is applied. The author also recommended that covering chips with slurry seal does not justify leaving problems with the seal coat unresolved or inadequately addressed. In case there is aggregate loss under traffic because of rain or other factors, the seal coat should not be covered with microsurfacing. The aggregate loss problem should be fixed in a different way before application of the microsurfacing. Significant shoving and bleeding have been occurring in cases where there has been a loss of aggregate of the chip seal and the seal has been covered with the microsurfacing. Sufficient embedment and a strong bond between the seal coat aggregate and the binder are important to ensure no loss of aggregate takes place under traffic or owing to rain. This can be achieved through proper construction and through the use of an appropriate antistripping agent. This is to ensure a strong bond between the binder and aggregate.

(c) Microsurfacing:

Solaimanian et al. (1998) reported that the construction of microsurfacing alone is not yet widely practiced throughout the state and the use of the chip seal as a surface treatment technique is much more common. In spite of this, microsurfacing has become an increasingly popular pavement rehabilitation alternative to seal coats and hot mix asphalt concrete (HMAC) overlays because it performs satisfactorily in most situations. However, reflection cracks that develop rapidly in microsurfacing are a major problem in areas where microsurfacing has been placed over pavements that show fatigue or alligator cracking. On the other hand, problems with aggregate loss, windshield damage, and rough riding surfaces discourage the wide use of chip sealing by itself. Thus, the two procedures have been combined to provide the benefits of both (better crack prevention and less water permeation provided by the chip seal, combined with the retention of aggregates and skid resistance provided by microsurfacing), while avoiding the disadvantages of each. Some of the districts apply chip seal/microsurface to extend pavement life a few additional years (ranging 3 to 5 years), with expectation that funds will at some point become available for a major rehabilitation with a hot mix overlay.

2.2.10 Virginia State Department of Transportation (VDOT)

Virginia Department of Transportation (VDOT) most commonly uses milling and overlay as a preventive maintenance treatment on pavements. The VDOT also has experience with slurry seal and cape seal. A detailed explanation of the treatment methods is described in this section.

2.2.10.1 Pre – Treatment Repair

(a) Milling:

Mokarem (2006) reported that milling is one of the pre-overlay methods incorporated in the preparation of the pavement for preventive maintenance treatment. Milling is a method effective for pre-overlay preparation and in turn increases the service life of the pavement. It can be implemented in areas where the pavement is too heavily cracked, thus preventing reflective cracking, in ruts at least 0.75 inches deep. Milling followed by surface treatment to a deteriorated pavement prevents the entry of water and can perform well on pavements carrying traffic of less than 2000 vehicles per day. An average service life increase of about 5 years is observed.

2.2.10.2 Preventive Maintenance Treatment

(a) Slurry Seal:

Slurry seals are recommended to be used in areas of low traffic and on stabilized shoulders as a maintenance treatment to seal the access roads. It can be used as a topping to a hot recycling surface. An open graded friction course can also be placed in a thin layer of 70 lb/ yd^2 in areas of wet conditions *(Maupin, 1986).*

(b) Cape Seal:

Solaimanian et al., (1998) reported that three cape seal projects were used as a case study in Virginia to analyze the effectiveness of cape seal. In all cases, a CRS-2 type emulsion was used for the seal coat, along with 0.4 inches maximum sized granite aggregate applied at rates in the range from 7.7 to 8.2 kg/m^2. The slurry covers the chips completely. In one of the test sections, there was a 30 day time delay between construction of the seal coat and application of microsurfacing, with considerable loss of aggregate and some windshield damage reported. In two other projects, there was a 3 day delay before slurry was placed over the chip seal. These two projects have been very successful and have demonstrated very good performance. The microsurfacing was applied at a rate of about 12 kg/m^2. The cost of the constructed Cape seal was reported to be about $1.30 to $1.40 per square meter, about half the cost of a 1.5 inches HMA overlay, which typically costs about $2.70 per square meter.

In summary, VDOT mainly treated the distressed bituminous surface pavements by milling and overlaying with a less than 2 inch HMA overlay.

2.2.11 Washington State Department of Transportation (WSDOT)

Li et al., (2008) reported that the Washington State Pavement Management System tracks the pavement condition over time and schedules the preservation efforts over a period of time. The most common tracking components consist of cracking, where pavement sections are more than 10 percent cracked; 0.4 inches of rutting, and or IRI greater than 2.8m/km. Pavement preservation is often first followed up by crack seal followed by HMA overlay every 10 to 16 years and Bituminous Surface Treatment every 5 to 8 years. One of the most common types of overlay used is 1.5 inches HMA overlay which functions well on all types of pavements for all traffic levels. The Bituminous Surface Treatment is, however, used on lower traffic levels with an annual average AADT of less than 2000.

2.2.11.1 Preventive Maintenance Treatment

(a) Paver placed surface treatment / Novachip:

Russell et al. (1998) reported that Novachip is a highly efficient technique used for preventive maintenance. The main advantages are excellent adhesion (no chip loss), reduced rolling noise (urban use), rapid application, and quick opening to traffic. Novachip as a surface treatment can be implemented on structurally sound pavement. It is not designed for bridging weak spots or to cover underlying pavement deficiencies. Adequate pavement repair to address alligator cracking or potholes is necessary to ensure good performance. Non-working cracks, which are less than ¼ inch in width, do not require sealing prior to the placement.

Novachip's use in the United States dates back to 1992, where sections were placed on state highways in Texas and Alabama. Novachip is reported to provide good to excellent service life for the three to five year monitoring periods reported.

(b) Other Treatments:

Amongst the various preventive maintenance techniques, fog sealing was seen to provide a service life of about 4 years when applied to the pavement. Slurry seals, however, do not perform well in cracked pavement conditions; this type of treatment is predicted to last for 3 to 10 years. The performance period of chip seals was 2 to 11 years when it was done after minor pre-repair work on the pavement. Based on the analysis by the WSDOT, it was followed that three pavement preservation strategies can be applied for particular conditions:

- HMA Overlay for pavements exhibiting cracking greater than10 percent of total pavement area, rutting greater than 0.4 inches, or IRI higher than 3.5 m/km.
- Bituminous Surface Treatment for pavements with cracking greater than 10 percent, or IRI higher than 2.8 m/km.
- Bituminous Surface Treatment and HMA Overlay for pavements exhibiting cracking greater than 10 percent, and IRI higher than 3.5 m/km.

These strategies were adopted by HDM-4 software as per the requirements *(Li et al., 2008).*

2.2.12 Other State Agencies

Kansas State Department of Transportation

In line with the LTTP SPS-3 Project, it was observed that Thin Hot Mix Asphalt Overlays and Chip Seals were an extremely effective means of surface treatment. The test sections that were implemented with these indicated that the treatment improved the ride quality and two-thirds of the test sections reacted positively. However, slurry seals did not prove to be effective in most of the sections. The method of crack sealing provided good results as it preserved pavement by prevention of penetration and incompressible material. As a result of the evaluation of pavement preservation techniques followed in 1995 SPS-3 projects, Kansas DOT has increased the implementation of crack sealing with a low reservoir for crack sealant. The service life imparted by this method is between 4 and 5 years. However, there is a direct influence of the timing of the sealing and the accepted practice is to crack seal one year and chip seal the pavement the next *(LTPP Findings*, *Pavement Preservation Compendium, 2000).*

One system of preventive maintenance of rutted asphalt pavement was by milling out two inches of the driving lane and replacing it with a 2 inch thick polymer modified HMA. This layer of HMA was then protected with a tack coat and a Plant Mix seal coat about ¾ inches to avoid distress to the pavement in the future. This provided the pavement with a service life of 6 years. This method did not prevent the rutting completely but however reduced the rate at which the rutting spread to the pavement *(Ardani, 1993).*

Felker et al. (2007) reported Fly Ash Slurry Injection Method (FASI) was used by Kansas DOT, on the I -70 route, to prevent the effects of transverse cracking and the reappearance of cracks on the asphalt pavement surface on the application of the overlay rehabilitation technique. The FASI is injected into the area below each crack through holes drilled into the pavement onto both sides of the pavement adjacent to the crack. These depressions are removed by milling once the curing of the slurry takes place and a bituminous overlay is then placed on the surface to finish it. This method extended the service life of the pavement and was found to be effective for each crack repair procedure. The process protects the pavement against transverse cracking owing to the effects of low temperature. Comparative data analysis has shown that this technique has extended the service life of the pavement by eliminating transverse crack depression to about 12 years.

Utah Department of Transportation

In 1995 Anderson reported that the preventive maintenance treatment and identification of pavement deterioration are based on factors such as, friction number, rut depth, and present serviceability index. The range of these factors for the application of thin HMA overlay are, Friction Number less than 35, rut depth greater than 0.5 inches and present serviceability index less than 1.5. In a particular case, with rideability (PSI) ranging between 2.1 to 3.1 and the presence of transverse cracking, crack sealing is performed before overlay.

Anderson (1985) recommended that until the rehabilitation of the pavement is performed, temporary functions like crack sealing and pothole repair should be followed to keep the standard of the pavement up to the ride quality. A multiple studies observation noted that the overlay effectiveness per inch of thickness is reduced as the thickness is increased. Thus, the policy of placing a minimum overlay thickness of 2.5 inches was used for improving the structural efficiency of the pavement. The thinner surfaces are appropriate where the condition of the pavement is good and the main intention is to improve the ride quality of the pavement.

Illinois Department of Transportation

Reed (1994) reported that the Illinois Department of Transportation initiated a single pass thin lift bituminous overlay policy to maximize the effect of maintenance effort. The preventive maintenance process consists of pavement patching, milling and crack control treatments that are supplemented by 1.25 to 1.5 inch bituminous overlay. The service life of such maintenance techniques is about 7 to 10 years. The Illinois DOT uses the Condition Rating Survey (CRS) to determine the pavement condition over which the preventive maintenance is to be applied. The CRS value influences the maintenance technique used on the pavement surface.

The thickness of the overlay applied is between 30 mm to 40 mm (1.25 in to 1.5 in). This overlay technique is effective for block cracking, weathering and raveling, and milling is usually recommended on the pavement to eliminate the distress problems. Several methods were used to predict the average life of the maintenance technique and it is between 7 to 10 years *(Reed, 1994).*

2.3 SUMMARY OF LITERATURE REVIEW FINDINGS

2.3.1 Treatment Types

An effective preventive maintenance practice is one which enhances the performance of the pavement and extends service life. The type of pavement maintenance treatment however is not the only factor that controls the effectiveness of a pavement. An important factor that controls the performance is the time of application of treatment. This is true for high volume roadways, as the age for preventive maintenance treatment shortens the rates of deterioration caused by the traffic increases. The different types of treatments available are listed and explained in the previous section *(Peshkin et. al., 2009)*. The most commonly used preventive maintenance treatment on flexible high-traffic volume roadway is shown in Table 6.

Table 6. Summary of preventive maintenance treatments on flexible high-traffic volume roadways

Rural Roadways			Urban Roadways		
<10,000 ADT	10,000 to 19,999 ADT	≥ 20,000 ADT	< 10,000 ADT	10,000 to 19,999 ADT	≥ 20,000 ADT
≥ 60% of States & Provinces report using the following:					
Crack Fill, Crack Seal, Thin HMA Overlay	Crack Fill, Crack Seal, Thin-Bonded Wearing Course, Cold Mill & Overlay	Crack Fill, Crack Seal, Thin HMA Overlay	Crack Fill, Crack Seal, Single Course Microsurfacing, Thin-Bonded Wearing Course	Crack Fill, Crack Seal, Multiple Course Microsurfacing, Cold Mill & Overlay	Crack Fill, Crack Seal, Thin HMA Overlay

Each of these treatments is described with respect to high volume traffic in the following sections.

Crack Seal: Crack Seal is the most common form of preventive maintenance pre-treatment used by most of the transportation agencies on roadways with low traffic volume. This method of treatment primarily prevents moisture infiltration in to the pavement structure, and thus reduces crack deterioration, roughness and rutting. While crack sealing addresses the cracks that open and close with temperature changes, crack filling addresses cracks which undergo little movement and does not require crack preparation.

Chip Seal: Chip seal is used significantly in treating low volume roads. Some state agencies have however also used this treatment on high volume roads. For instance, California allows chip seals to be used on roads with average ADTs up to 30,000 and the United Kingdom uses chip seal commonly on roads with greater than 20,000 ADT. It is also sometimes referred to as seal coat or bituminous surface treatments. They are normally used to seal the pavement with cracks so that the friction of the surface can be improved *(Cuelho, 2006).*

Paver placed surface treatment or Ultra-thin Bonded Wearing Course: This is also referred to by many agencies as Novachip, a thin bonded wearing course in an alternative to chip seal. It consists of gap-graded polymer modified HMA layer placed on a tack coat of heavy, a polymer modified asphalt emulsion. WSDOT and ODOT reported the use of this treatment for preventive maintenance.

Microsurfacing: Microsurfacing uses polymer modified emulsion binder, higher quality aggregates and an additive for controlling set. It is used to improve the surface friction characteristics, fill ruts when up to 1.5 inches, and address irregularities. It has been implemented on both low and high volume roadways *(Peshkin et al., 2009).*

Thin HMA overlay: Thin HMA overlay is a combination of aggregate, asphalt binder and normally is applied to the pavement with a thickness less than 2 inches. In certain states however the thickness of application used is greater than 2 inches. Three different types of HMA overlays are common to preventive maintenance treatments; however each of these differ in gradation of the aggregate.

- Dense graded overlays
- Open graded friction courses
- Stone matrix asphalt

This treatment is used on high-traffic volume roadways. The use of this treatment is not limited by the weather or adverse conditions when emulsion-based treatments are not recommended.

Other treatments: The flexible slurry system implemented by MnROAD is constructed using the microsurfacing machine; however, it is less brittle than the microsurfacing mixture. The slurry since it is used as a surface course, can take a traffic range of less than 200,000 ADT and is not recommended for low traffic areas (*MnROAD, 2005*).

The APTech research in 2009 stated that the smooth seal practiced by Ohio DOT is placed as a thin layer of about 0.75" to 1". This method is applicable against distresses such as raveling, cracking, and delamination of the pavement. It provides flexibility and improves adhesion of the mix to the base of the pavement. These treatments however do not have a specific service life since it depends on the conditions and traffic present on the pavement.

The current practices in pavement preservation on high traffic volume roadways are summarized in Table 7.

Table 7. Summary of reported treatment use for state highway agencies

Type of Treatment	Indiana	Minnesota	Michigan	New York	Ohio	Virginia
Cape Seal	-	-	✔ ⊘	✔	-	✔
Chip Seal : Single Course	✔ ⊘	✔	✔	✔ ⊘	✔ ⊘	✔ ⊘
Multiple Course	⊘	✔	✔	✔ ⊘	⊘	-
Crack Seal	✔	✔ ⊘	⊘	✔	✔	✔
Crack Filling	✔	✔	✔	✔	-	✔
Fog Seal	✔	✔ ⊘	⊘	⊘	-	✔ ⊘
In-place Recycling: Cold	-	✔	-	✔ ⊘	-	-
Hot	-	-	-	✔	-	-
Microsurfacing	✔	✔	✔	⊘	✔	✔ ⊘
Mill and overlay	-	✔	✔	✔	✔	-
NovaChip	✔	✔	✔	✔	✔ ⊘	✔
Paver placed surface treatment	-	-	-	✔	-	-
Polymer modified HMA	✔	✔	✔	✔	✔	-
Slurry: Flexible Slurry		✔ ⊘	⊘	-	-	-
Quick Set Slurry	-	-	-	✔	-	-
Smooth Seal	-	-	-	-	✔	-
Thin HMA overlay	✔	✔	✔	✔	✔	✔
Ultra-thin HMA	-	⊘	✔	✔	✔	⊘

✔ Agency reports using treatment regularly on high-traffic volume roadways.

⊘ Agency notes some concern regarding treatment's durability on high-traffic volume roadways.

2.3.2 Treatment Design Considerations

The treatment considerations for each of the treatments used differ depending on the traffic conditions that they are subjected to. For high traffic conditions, the design is modified accordingly by some state agencies to adapt the treatment. According to the literature search findings, a summary of the applications and the design considerations used can be described as below.

Chip Seal: The chip seal installations in high traffic volume roadways in California, Oklahoma, and Virginia have a considerable insight on the factors that affect the chip seal. Some of the factors that influence the chip seal are *(Shuler, 1998)*:

1. Use of one-aggregate thick application rate to reduce excess stone
2. Pre-coating the aggregate with binder prior to application to enhance adhesion
3. Use of polymer modified binders to enhance adhesion
4. Application of choke stone to prevent larger aggregates from coming loose
5. Sweeping of the surface after rolling
6. Use of a pilot car for 1 to 3 hours after construction to help embed chips

Some other agencies follow chip seal applications with fog or crack sealing. Galehouse et al. (2003) reported that in one region in Colorado applies fog seals within 2 to 10 days of chip seal application. In California, San Diego County successfully using chip seal with latex modified emulsion over fabric, achieved a service life of 18 years, with the fabric still intact and the base layer maintaining good condition. However, this is not recommended in areas with a steep grade *(Kuennen 2005)*. Most states report successfully using chip seal application on a roadway subjected to low traffic volume.

Microsurfacing and Slurry Seal: Microsurfacing has been used extensively, and performed well, on high traffic volume roadways, while slurry seals have been used on high-traffic volume roadways with special aggregate gradations *(Raza, 1992)*.

Ultra-thin Bonded Wearing Course: Caltrans has developed a provision for thin bonded wearing courses, including specific requirements for allowable gradations and characteristics.

The main properties of the aggregate used include shape, number of crushed faces, wear resistance and clay control *(Caltrans 2008)*.

Thin HMA Overlay: Thin HMA overlays on flexible pavements are found to be an effective method of preventive maintenance against various distresses. This treatment however performs better with better pavement conditions. The benefits include reduction in rutting and cracking distresses like those of transverse and longitudinal cracking *(Chou et al., 2008)*.

2.3.3 Treatment expected lives

One way to describe the effectiveness of the preventive maintenance treatment is by the increase in service life that the treatment contributes to the pavement. The literature review process also indicated that the treatment which increased the service life of the pavement is microsurfacing. While, the North American highway agencies have reported that the service life of thin HMA pavements varies between 2 years minimum, 7 to 8 years mode and about 9 to 10 years at a maximum *(Irfan et al., 2009)*. The various other service life limitations reported by different agencies are about 6 years (NYSDOT), 8 years (NCHRP), and about 8 to 11 years (FHWA). The performance of the pavement varies according to the agency. A summary of the findings of the literature review are as shown in Table 8.

Table 8. Summary of state DOT treatment life reported in literature

TREATMENT	STATE HIGHWAY AGENCY				
	Indiana[A]	Minnesota[B]	Michigan[C]	New York[D]	Ohio[E]
Chip Seal	3 - 4	3 - 6	3 - 6	2 – 4	5 - 7
Crack Seal	4	3	2	-	2 - 3
Thin HMA Overlay	3 -13	5 -8	5 - 10	5 – 8	8 - 12
Fog Seal	-	1 - 2	-	-	-
Slurry Seal	-	3 - 5	-	-	-
Microsurfacing	-	7 - 10	3 -5	5 – 8	5 - 8
Quick Set Slurry	-	-	-	3 – 5	-
Paver Placed HMA	-	-	-	5 – 8	7 - 12
Polymer-Modified HMA	-	-	-	5 – 8	-
Heater Scarified HMA	-	-	-	2	-

[A] (Labi and Sinha 2004)
[B] (Johnson 2000)
[C] (Galehouse 2003)
[D] (NYSDOT 2005)
[E] (ODOT 2001)
(-) – Information not received

2.4 PENNSYLVANIA STATE DEPARTMENT OF TRANSPORTATION (PENNDOT) FINDINGS

The Pennsylvania State Department of Transportation dictates the various Bituminous Pavement and Preventive Maintenance Guidelines in accordance with Publication 242 *(2010)*.

2.4.1 Pre-Treatment Repair

(a) Leveling Course:

The guidelines indicate the pre-overlay surface preparation for bituminous overlay procedures. The method used for pre treatment reported is placing a leveling course of about 60 to 100 pounds per square yard depending on the aggregate used. The leveling course corrects the profile of the existing pavement and is considered as a part of the binder or wearing course for design purposes *(Pub 242, Penn DOT, 20010).*

(b) Milling and Overlay:

Another method of pre-overlay repair is to mill the pavement surface. When the base in a stable condition and the removal of the surface layer does not affect the other characteristics of the pavement, milling and overlay is found to be effective. During milling, it is preferred to leave about 1.5 inches of the existing bituminous material in place to retain the structural value and the base stability. The service life of the pavement post maintenance was 3 years. The technique of milling the entire old asphalt and replacing with a new overlay extends the service life by about 2 years. The use of Milling and Inlay Strategy is commonly countered by the effects of severe surface cracking. This can be followed up by the application of a SAMI layer during the placement of an overlay. Additionally, the SAMI layer can be incorporated with a chip seal as part of the SAMI to counter the effects of rutting. Penn DOT also implements the concept of leveling the area and placing of an overlay *(Morian et al., 2005).*

2.4.2 Preventive Maintenance Treatment

(a) Slurry Seal:

Publication 242 indicated that slurry seals and should not be used on interstates. The surface treatments such as bituminous leveling course or seal coat for a combination of distresses such as minor rutting, minor cracking and loss of fine aggregates shall be used for low volume roadways. However, such treatments do not upgrade the structural capacity of the pavement.

(b) Friction Bearing Courses:

The publication 242 specifies the criteria for selection of the appropriate treatment to the pavement such as seal coat, slurry seal and surface treatment. One of the criteria of decision making is the ADT. It indicates the application of friction bearing surface courses and the specifications with regards to the ADT and the application rate. The following table from publication 242 defines the application of various treatments depending on the traffic conditions.

Table 9. Applicable Roadway ADT for Chip Seal, Slurry Seal and other surface treatment – Penn DOT, Publication 242 Guidelines

Current ADT	Chip Seal	Slurry Seal	Surface Treatment
0 to 800	✔	✔	✔
801 to 1,500	✔	✔	✔
1,501 to 3,000	2	✔	2
3,001 to 5,000	2	✔	2
5,001 to 12,000	2	1	2
12,001 to 20,000	3	1	2
>20,000	✕	✕	✕

Notes:
1 - Use only if base is good and existing surface is an HMA surface
2 - Use only if traffic is controlled during and after construction, and aggregate is precoated or held to 1.0 percent passing the #200 sieve.
3 - Use only if traffic is detoured or lane is closed for 24 hours, and aggregate is precoated or held to 1.0 percent passing the #200 sieve.

(c) Latex modified Emulsion:

Penn DOT Publication 242 states that another means of surface treatment is the Latex–modified emulsion paving course for a structurally sound pavement which does not require much repair to the base of the pavement. Owing to its ability to cure quickly and to perform under controlled traffic conditions, it can be used as an alternative to seal coats and slurry seals. It can be used directly without any prior rut filling. It restores the pavement surface without any additional structural overlay. The selection of this type of restoration method is influenced by the ADT, type of restoration that is required such as, leveling course, rut filling and wearing course. The pavement condition rating requires to be done before deciding on the type of restoration or preventive maintenance on bituminous pavement *(Pub 242, Penn DOT, 20010).*

A Skid Resistance Level designation is made for an aggregate that is used in the restoration process; this is a result of friction tests. The bituminous wearing course used is based on the Skid Resistance Level designation of the aggregate, and the traffic conditions. Latex modified emulsion paving courses are used to prevent the problem of near surface rutting especially for interstates with high traffic conditions where the average daily loadings exceed 1000 ESALs. However, these may not be used on pavements with only 2 to 3 inches of bituminous material. Publication 242 also specifies the grading of the superpave bituminous material that can be used in the bituminous overlay for pavements *(Pub 242, Penn DOT, 2010).*

(d) Thin HMA Overlay:

In case of thin bituminous overlays, the Publication 242 states that on interstates, HMA wearing course overlays less than 1.5 inches shall not be placed until it meets the conditions specified by Penn DOT. The conditions required to be satisfied are

- The existing pavement surface is bituminous,

- The existing pavement is structurally sound; less than 2% of the pavement requires patching,
- Surface drainage is good, or will be upgraded to good, with this project,
- Subsurface drainage is good, or will be upgraded to good, with this project, and
- No structural upgrade of the pavement is required *(Pub 242, Penn DOT, 20010).*

According to a case study conducted by Baladi et al. (2002), a particular stretch of I-78 was rehabilitated by milling the existing asphalt concrete pavement, repairing the deteriorated joints, and placing of an asphalt concrete overlay performed well increasing the service life by 3 years. In summary, Penn DOT recommends the use of seal coats, slurry seals, and surface treatments except for interstate pavements. The use of these treatments can be determined in accordance with Publication 242. While bituminous surface treatment or leveling courses correct deficiencies such as minor rutting, minor cracking, and loss of aggregate, these treatments are restricted to pavements with a good structural condition. Latex modified emulsion paving courses are ideal for restoring surface distresses on pavements with a sound structural composition. The guidelines also recommend overlay thickness not less than 1.5 inches for interstate pavements.

The APTech study related to Strategic Highway Research Program (SHRP 2R26, 2007), indicates that the Pennsylvania DOT practices a range of treatments for preventive maintenance. These treatments include chip seal, crack seal, fog seal, microsurfacing, polymer modified HMA overlay, thin HMA overlay, and ultra thin HMA. The preventive maintenance practices applied in the various districts in Pennsylvania are discussed in chapter 4.

3.0 NATION WIDE SURVEY

3.1 INTRODUCTION

In order to understand pavement preservation practices at other State Highway Agencies (SHA's) in the same general region as Pennsylvania a nationwide survey was performed. The survey questionnaire was sent to nine states, namely New York, Ohio, Virginia, Maryland, Michigan, Minnesota, West Virginia, Indiana, and Texas. Five states including New York, Ohio, Virginia, Michigan, and Minnesota responded to the survey questionnaire. The state responses were compiled to obtain a general idea of the techniques of pavement preservation, bituminous overlay techniques, service life, thickness of overlay, and the best practice used. The survey questionnaire used for the nationwide survey is attached in Appendix A. The responses from each of the State Highway Agency are also included in Appendix A.

The nationwide survey was distributed to the states during the first week of November 2008. Each survey recipient was sent a set of nine questions. Since the practices in each state depend on various factors, the representatives were asked to differentiate between pavement preservation and preventive maintenance. The objective of the questionnaire was to identify the techniques used for preservation and the best practices for the application of hot mix asphalt overlays. Based on the current practice of pavement preservation, the agencies were also asked to describe the characteristics of the methods based on life cycle cost, cost of construction, thickness of overlay used, and mix design components. In addition, each state has different guidelines for pavement preservation and preventive maintenance. States were asked to enumerate these guidelines to identify a list of techniques and methods of maintenance. Preventive maintenance and pavement preservation are evolving strategies, the questionnaire also asked to highlight innovations or specific technologies used in the preservation and maintenance of bituminous overlays.

The responders for each agency are as follows:

Virginia Department of Transportation (VDOT)

Contact Person:

Trenton M. Clark, P.E.
Asphalt Pavement Field Engineer
Culpeper, Staunton, and NOVA (Northern Virginia) Districts
PO Box 308
551 Mechanic Street
Luray, VA 22835
(540) 860-2495
(540) 743-7249 (fax)

Michigan Department of Transportation (MDOT)

Contact Person:

Brandy Donn, P.E.
Pavement Management Engineer
North Region Office
Michigan Department of Transportation
1088 M-32 East
Gaylord, MI 49735
(989) 731-5090
donnb@michigan.gov

New York Department of Transportation (NYSDOT)

Contact Person:

Zoeb Zavery, PE
NYS DOT

Materials Bureau - POD 34
50 Wolf Road
Albany, NY 12232
(518) 485-5277
zzavery@dot.state.ny.us

Ohio Department of Transportation (ODOT)

Contact Person:

Adam Au
Office of Pavement Engineering,
Ohio DOT
(614) 995-5992
Adam.au@dot.state.oh.us

Minnesota Department of Transportation (MnDOT)

Contact Person:

Roger Olson
Minnesota Department of Transportation
Office of Materials
1400 Gervais Ave.
Maplewood, MN 55109
(651) 366-5517
(651) 366-5461 fax
roger.olson@dot.state.mn.us

3.2 SUMMARY OF STATE SURVEY RESPONSES

3.2.1 Virginia Department of Transportation (VDOT)

In response to the survey, VDOT stated that it does not differentiate between pavement preservation and pavement maintenance. According to VDOT, pavements in good condition primarily receive thin HMA overlay or surface treatments. In case of extensive deficiencies the state uses patching, milling, or applies a thicker overlay to improve performance. VDOT does not have any formal guidelines for determining the pavement preservation technique. The treatment selection is based on past experience and on the discretion of the pavement manager. Pavements in poor condition require an engineering evaluation to determine if they need restorative maintenance or reconstruction. On the other hand, pavements in good condition receive maintenance/preservation accordingly.

The various techniques used by VDOT to preserve bituminous surfaced pavements are thin HMA overlays, surface treatments, microsurfacing, and slurry seals. VDOT has also experimented with Novachip or thin overlay treatment, straight overlay or mill and replace methods. It primarily uses dense-graded HMA for overlays, but in some cases use Stone Matrix Asphalt with PG binder. Most of VDOT's projects consist of either a straight overlay or a mill and replace. For high traffic volumes and interstates, the stone matrix asphalt (SMA) overlay is observed to extend the service life by about 12 to 15 years. Although the cost of SMA overlay is approximately 25 to 35 percent higher than dense graded mixes, but provides a longer life. Most SMA overlays are 1.5" to 2" using either PG 70-22 or PG 76-22 for the binder. VDOT states that the three best treatments are crack seal, patching and thin bonded wearing course or thin HMA overlay.

VDOT reports that the three best treatments implemented on both rural and urban roadways are crack seal with a "good cost-to-benefit ratio", patching, and thin bonded wearing course or thin HMA overlay (1.5 in thick). However, VDOT reported a poor experience with chip seals and microsurfacing on rural and urban roadways *(Peshkin et al., 2009).*

Table 10. Virginia Department of Transportation Comparative Summary

VIRGINIA DEPARTMENT OF TRANSPORTATION					
Treatment Type	**Literature Review Findings**			**State Agency Survey Findings**	
	Application Thickness (inches)	**Traffic Requirements** (ADT)	**Treatment Life** (yrs)	**Treatment Use**	**Observations**
Pre-Treatment Repair					
Milling and Overlay	0.75	< 2000	5	✔	1.5" to 2", dense graded
Preventive Maintenance Treatment					
Slurry Seal	-	Low	3	✔	secondary roads
Cape Seal	0.4	Low to High	3 to 5	✔	secondary roads
Thin HMA Overlay	< 0.2"	High	5 to 8	✔	< 2"
Microsurfacing	-	High	5 to 7	✔	high traffic roads
NovaChip	-	-	-	✔	Innovative Technology
Stone Matrix Asphalt	-	-	-	✔	1.5" - 2" thick, 12 - 15 yrs

3.2.2 Michigan Department of Transportation (MDOT)

MDOT follows the AASHTO definition for pavement preservation whereas, pavement maintenance can be defined as the routine work performed to maintain and preserve an adequate level of service.

MDOT uses various preventive maintenance techniques such as crack treatments, chip seal, single and double course microsurfacing for flexible pavements. HMA overlays are used on pavements showing raveling, longitudinal and transverse cracking, and minor block cracking.

Ultra thin HMA overlays are used to address low severity cracking, weathering and raveling, and bleeding. These treatments restore friction and ride quality. The bituminous overlays are maintained by using crack sealing, chip sealing, microsurfacing, and maintaining positive drainage. HMA overlays are used on pavements with a good base condition, and a uniform cross section. The overlay is placed on pavements with a minimum remaining service life of 3 years. The visible surface distress addressed may include moderate raveling, longitudinal and transverse cracks and small amounts of block cracking.

MDOT does not have a method of preservation that is better than others. Although the HMA overlay is considered as a high level surface treatment it may not be the most effective method of preserving all pavements. Currently, MDOT is updating their "Capital Preventive Maintenance Manual", a document for construction engineering, testing, inspection, and services for preventive maintenance projects. MDOT's current practice is based on the "mix of fixes" approach. The decision of treatment applied on the pavement section is influenced by the previous experience of the DOT.

Table 11. Michigan Department of Transportation Comparative Summary

MICHIGAN DEPARTMENT OF TRANSPORTATION					
Treatment Type	**Literature Review Findings**			**State Agency Survey Findings**	
	Application Thickness (inches)	**Traffic Requirements** (ADT)	**Treatment Life** (yrs)	**Treatment Use**	**Distress Conditions**
Pre-Treatment Repair					
Crack Treatment	-	-	up to 3	✔	-
Preventive Maintenance Treatment					
Chip Seal	-	Low	3 to 6	✔	-
Single Course Microsurfacing	-	-	3 to 5	✔	-
Multiple Course Microsurfacing	-	-	4 to 6	-	-
Thin HMA Overlay	1.5	-	3 to 5	✔	-
Ultra Thin HMA Overlay	0.75	-	3 to 5	✔	Low severity cracking, raveling/weathering, friction loss, and low severity bleeding
Rehabilitation Treatment					
Cold Milling and Overlay	-	-	-	✔	2.5" thickness

3.2.3 New York Department of Transportation (NYSDOT)

The New York State DOT considers preventive maintenance a component of pavement preservation similar to the Federal Highway Association's definition, which attributes three primary components to a pavement preservation program: preventive maintenance, minor nonstructural rehabilitation, and routine maintenance activities.

NYSDOT representative stated that it refers to its “Comprehensive Pavement Design Manual, 2005” for selecting specific pavement preservation treatments, as well as rehabilitation and reconstruction methods. The most effective preventive maintenance treatment is specific to each pavement section, and is a function of the pavement’s age and condition; it is also the treatment that best maintains or extends the service life of the pavement without shortening the useful life of the previous treatment. The techniques used for preservation by NYSDOT are crack sealing, mill and fill, thin overlays, microsurfacing, pavement preserved surface treatment, heater scarification without overlay, and cold in-place recycling.

The pavement is eligible for a preventive maintenance treatment when distresses are minimal or of low severity—generally within the third or fourth year of its service life, or a rating of “7” on the Department’s scale of 1 to 10, which typically occurs 10 to 12 years following the previous treatment’s application. Thin HMA overlays have been found to perform best at the early stage of deterioration, while 1.5-in HMA overlays can perform well at the later stage.

Some of the treatments classified by NYSDOT as preventive maintenance include thin surface treatments such as chip seal, slurry seal, and microsurfacing. Additionally, pavement preservation treatments include mill and fill and cold in-place recycling. NYSDOT has also experimented with rubber modified chip seal, and surface treatment with sand seal.

According to NYSDOT’s response to the SHRP2 survey regarding preventive maintenance on high-traffic volume roadways, NYSDOT considers crack sealing the best value for the cost and the first line of defense to retard future deterioration. They also report that thin HMA overlays (1.5 in thick) are the most widely used and considered them essentially to be failure proof. Multiple course microsurfacing is also considered “best value for surface sealing.”

NYSDOT does not use fog seals and rejuvenators on travel lanes because of the potential for friction problems. The Department also does not use cold in-place recycling on high-traffic volume roadways due to traffic control issues and possible performance deficiencies. The paver placed surface treatment used by NYSDOT seals existing road surface and provides a new, skid-resistant, ultrathin (5/8 to 0.75 in.) wearing course in one simultaneous operation.

Table 12. New York Department of Transportation Comparative Summary

NEW YORK DEPARTMENT OF TRANSPORTATION					
Treatment Type	**Literature Review Findings**			**State Agency Survey Findings**	
	Application Thickness (inches)	**Traffic Requirements** (ADT/AADT)	**Treatment Life** (yrs)	**Treatment Use**	**Distress Conditions**
Pre-Treatment Repair					
Crack Sealing	-	-	-	-	-
Heat scarification	1 to 2	-	2	✔	-
Preventive Maintenance Treatment					
Chip Seal	0.5	Low (<2000 AADT)	2 to 4	✔	-
Microsurfacing	0.4 to 0.8	-	5 to 8	✔	-
Paver placed surface treatment	-	-	4 to 6	-	-
Polymer modified HMA	0.8 to 1	-	5 to 8	✔	-
Slurry Seal	0.2 to 0.6	Low to High ADT	3 to 5	✔	-
Thin HMA Overlay	1.5 to 2	-	5 to 8	✔	applied at early stages of distress
Rehabilitation Treatment					
Cold-in-place Recycling	-	-	-	✔	-

3.2.4 Ohio Department of Transportation (ODOT)

ODOT refers to its Preventive Maintenance Guidelines and Pavement Condition Rating System to describe the pavement distress and decide on the ideal preventive maintenance treatment. ODOT "Pavement Preventive Maintenance Guidelines," defines preventive maintenance and pavement preservation as follows:

Preventive Maintenance is defined as a planned strategy of cost effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, extends the service life, and maintains or improves the functional condition of the system without substantially increasing structural capacity *(ODOT 2001)*.

Pavement Preservation is considered to be the sum of all activities undertaken to provide and maintain serviceable roadways; this includes Reactive (a stop gap measure that keeps a failing pavement at an acceptable serviceability, and is seldom cost-effective).and Preventive Maintenance as well as Minor and Major Rehabilitation *(ODOT 2001)*.

The ODOT preventive maintenance guidelines list the following methods as effective preventive maintenance and preservation practices: Crack seal, chip seal, microsurfacing, polymer-modified asphalt concrete, and Thin HMA overlays. These treatments are used to prevent distresses such as, potholes, de-bonding, cracks, rutting, and transverse cracking. ODOT preventive maintenance guide summarizes the preventive maintenance treatments, traffic, cost and service life as shown in Table 13.

Table 13. Preventive Maintenance summary as shown in Ohio Department of Transportation – Preventive Maintenance Guidelines

Pavement Applications		Crack Sealing	Chip Seal	Micro – surfacing	Polymer modified asphalt concrete	Thin Hot mix overlay	Drainage Preservation
Pavement Surface	Concrete	✔	-	-	-	✔	✔
	Asphalt	✔	✔	✔	✔	-	✔
Reasons For	Friction	-	✔	✔	✔	-	-
	Rideability	-		✔	✔	✔	-
	Raveling	✔	✔	✔	✔	-	-
	Rutting	-	-	✔	✔	-	-
	Cracking	✔	✔		✔	✔	-
	Oxidation		✔	✔	✔	-	-
	Water	✔	✔	✔	✔	-	✔
Traffic	Low Volume*	✔	✔	✔	✔	✔	✔
	High Volume**	✔	-	✔	✔	✔	✔
	Maximum Speed***	-	-	-	Type A	-	-
Average Cost	Weight / Area	0.60 - 1.00 $ per lb	1.00 - 1.7 $ per SY	1.25 - 2.00 $ per SY	2.00 - 4.00 $ per SY	2.50 - 3.50 $ per SY	-
	Lane Mile [a]	1000 - 4000 $	8000 - 12000 $	8000 - 16000 $	14,000 - 25,000 $	17,000 - 25,000 $	2,000 - 5,000 $
Average Life (years)		1 to 4	5 to 8	5 to 8	7 to 12	8 to 12	1 to 5

* (<2500 ADT)
** (> 2500 ADT)
*** < 45 mph
[a] shoulders not included

The Guidelines also discuss how to identify a candidate to receive an HMA overlay by querying the ODOT pavement management system for pavement condition rating. Project selection is determined pending further field review by the pavement review team.

Although the cost effectiveness of different preventive maintenance techniques are currently under study, single layer chip seals have proven to be the most cost effective treatment, at roughly $13,000 per lane mile and lasting 3 to 5 years. However, ODOT's best treatment for high-traffic volume roadways is a thin HMA overlay (≤ 2 in thick), which is capable of providing structural benefit, especially upon repeated applications.

Table 14. Ohio Department of Transportation Comparative Summary

OHIO DEPARTMENT OF TRANSPORTATION					
Treatment Type	**Literature Review Findings**			**State Agency Survey Findings**	
	Application Thickness (inches)	**Traffic Requirements** (ADT/AADT)	**Treatment Life** (yrs)	**Treatment Use**	**Distress Conditions**
Pre-Treatment Repair					
Crack Sealing	-	-	2 to 3	✔	-
Milling and Overlay	2	-	-	-	-
Preventive Maintenance Treatment					
Single Layer Chip Seal	0.125	< 2500 ADT or < 250 ADTT	5 to 7	✔	3 to 5 yrs
Microsurfacing	-	Medium to High ADT	5 to 8	✔	-
Polymer modified HMA	0.6 to 0.75	Medium to High ADT	7 to 12	✔	-
Thin HMA Overlay	2	High ADT	8 to 12	✔	-
Other Treatment					
Smooth Seal	0.75 to 1	High ADT	-	-	-
Fine Graded Polymer AC	-	<1500 ADTT	-	-	-

3.2.5 Minnesota Department of Transportation (MnDOT)

MnDOT considers pavement preservation and pavement maintenance proactive and reactive tools, respectively. Typical preservation techniques include crack seal, chip seal, microsurfacing, and thin HMA overlays, while patching and spot overlays are common maintenance techniques. Thin HMA overlays used for pavement preservation are those less than
2 inches thick and used to restore ride where there is “some significant surface distress.”

Milling and overlay has proven to be an effective method for surface preparation. The agency stated that a variation of microsurfacing method as a pre-overlay treatment being used was Flexible Slurry which is a microsurfacing product with a softer base binder and higher asphalt content. For high-traffic volume roadways, MnDOT reported success in using chip seals and microsurfacing due to the presence of “strong” specifications and training, as well as improved design and construction methods. Also, ultra-thin bonded wearing courses have performed well over the past decade, while MnDOT has experienced an unacceptable number of crack sealing failures. A summary of the findings from the state survey for Minnesota are summarized in Table 15.

Table 15. Minnesota Department of Transportation Comparative Summary

MINNESOTA DEPARTMENT OF TRANSPORTATION					
Treatment Type	**Literature Review Findings**			**State Agency Survey Findings**	
	Application Thickness (inches)	**Traffic Requirements** (ADT/AADT)	**Treatment Life** (yrs)	**Treatment Use**	**Distress Conditions**
Pre-Treatment Repair					
Crack Sealing	0.75	-	3	✔	-
Milling and Overlay	2	-	-	✔	-
Preventive Maintenance Treatment					
Single Layer Chip Seal	0.125	< 2500 ADT or < 250 ADTT	5 to 7	✔	3 to 5 yrs
Fog Seal	-	-	1 to 2	-	-
Slurry Seal	0.5	-	3 to 5	-	-
Microsurfacing	0.75	High ADT	7 to 10	✔	-
Thin HMA Overlay	0.75 to 1.5	High ADT	5 to 8	✔	< 2", high severity
Other Treatment					
Flexible Slurry System	-	Low to High ADT	5 to 8	-	-

The comparison of preventive maintenance treatments from the survey and literature review summarize that most states use Crack seal and Milling & overlay as a pre-treatment repair. Whereas, chip seal, slurry seal, microsurfacing, and thin HMA overlays are the most common preventive maintenance treatments. Certain states also use different treatments such as flexible slurry in Minnesota, smooth seal in Ohio. Table 16 summarizes the preventive maintenance treatments used by the various states based on the survey response and the results of a nationwide study of survey practice (SHRP2) conducted by APTech in 2009 *(Peshkin et al, 2009).*

Table 16. Summary of State DOT treatment use

Type of Treatment	Minnesota	Michigan	New York	Ohio	Virginia
Cape Seal	-	✔ ⃠	✔	-	✔
Chip Seal : Single Course	✔	✔	✔ ⃠	✔ ⃠	✔ ⃠
Multiple Course	✔	✔	✔ ⃠	⃠	-
Crack Seal	✔ ⃠	⃠	✔	✔	✔
Crack Filling	✔	✔	✔	-	✔
Fog Seal	✔ ⃠	⃠	⃠	-	✔ ⃠
In-place Recycling: Cold	✔	-	✔ ⃠	-	-
Hot	-	-	✔	-	-
Microsurfacing	✔	✔	⃠	✔	✔ ⃠
Mill and overlay	✔	✔	✔	✔	-
NovaChip	✔	✔	✔	✔ ⃠	✔
Paver placed surface treatment	-	-	✔	-	-
Polymer modified HMA	✔	✔	✔	✔	-
Slurry: Flexible Slurry	✔ ⃠	⃠	-	-	-
Quick Set Slurry	-	-	✔	-	-
Smooth Seal	-	-	-	✔	-
Thin HMA overlay	✔	✔	✔	✔	✔
Ultra-thin HMA	⃠	✔	✔	✔	⃠

✔ Agency reports using treatments regularly on high-traffic volume roadways.

⃠ Agency notes some concern regarding treatment's durability on high-traffic volume roadways.

3.3 LONG TERM PAVEMENT PERFORMANCE (LTPP)

LTPP database is a large collection of data and information on the performance of selected in-service pavement test sections. The LTPP Standard Data obtained summarizes the various conditions and characteristics of preventive maintenance treatments. The main objective of LTPP review is to summarize these preventive maintenance practices applied to selected pavement sections by different state agencies. The results of the LTPP data, survey and literature review are compared to analyze the applicability of preventive maintenance treatment methods by different state agencies. The main treatment methods reported in the LTPP data are chip seal, crack seal, asphalt seal, and slurry seal. The various surface conditions that influence the preventive maintenance techniques such as pre-overlay repair, pavement temperature, crack type, and crack severity are also compared using the LTPP data.

The following sections summarize findings of the LTPP data for the different preventive maintenance treatments and the factors influencing their application. A detailed view of the data extracted from the LTPP study is presented in Appendix B.

3.3.1 Chip Seal

Most of the states report that chip seal is used for longitudinal cracking, edge cracking, block cracking, and transverse cracking. The chip seal used is an aggregate seal or a single course chip seal, with an average ambient temperature of 75°F and an actual pavement temperature of about 150°F. However, chip seal was applied to the pavement with a normal surface condition for a low severity cracking. The average seal thickness applied is about 0.3 inches. In case of transverse cracking, the application thickness ranges from 0.15 inches to 0.4 inches for different states for low severity cracking under normal surface condition. While a medium level edge cracking was addressed with 0.5 inch thick chip seal, a medium level alligator cracking for a badly oxidized surface condition was addressed with a 0.3 inch thick chip seal. In most cases, the form of chip seal applied at the different states is a combination of aggregate chips and asphalt.

3.3.2 Crack Seal

The LTPP data indicates that crack sealing is used by most state agencies against distresses such as longitudinal cracking, transverse cracking, and alligator cracking. While Indiana DOT addresses low severity longitudinal cracking by applying crack seal of 0.37 inch depth at an ambient temperature of 86°F, Michigan uses a 0.4 inch thickness and an ambient temperature of 84°F. The data also indicates that Pennsylvania applied crack seal at a higher temperatures and a depth of about 0.1 inch. The data also indicated that while most states used 0.1 inch depth seal for medium severity cracks, while transverse and edge cracks were treated with 0.5 inch depth crack seal.

3.3.3 Slurry Seal

The LTPP data also indicated that slurry sealing was used to prevent distresses such as transverse cracking, block cracking, and longitudinal cracking. Slurry seal is applied mainly to pavements exhibiting low severity cracking. While Indiana DOT used an ambient temperature of about 86°F, states such as Maryland, Michigan, Minnesota, New York and Pennsylvania also exhibit a similar range of temperature between 80°F to 100°F.

3.3.4 Specific Pavement Studies – Pavement Overlay

The LTPP data for specific pavement studies including preventive maintenance treatments for Minnesota and New Jersey indicated that in most cases, the thickness of the AC overlay or Thin HMA overlay varies between 1.5 to 2 inches. While the mean thickness of the HMA overlay on

HMA pavement surface is about 2 inches, the thickness of the overlay on the existing original pavement layer is about 1.5 to 3 inches. The comparative case study of the material indicated that the thickness of a friction course overlay on an existing asphalt pavement is about 1 inch.

3.3.5 Specific Pavement Studies - Overlay Thickness

According to the LTPP data case study for the two states Maryland and New Jersey represent that the thickness of overlay applied to the pavement in separate lifts. While the thickness of the hot mix asphalt overlay varies from 1.3 to 2.6 inches in Maryland, the thickness varies from 2.5 to 4 inches in New Jersey. However, the thickness of recycled asphalt overlay applied varies between 2 to 3 inches for Maryland and New Jersey. The SHRP pavements laid in Maryland show a thickness of 1.5 to 2 inches for the second and the third lift.

The FHWA report, FHWA-RD-01-168, on Rehabilitation of Asphalt Concrete Pavements details the use of LTPP data or the Special Pavement Studies (SPS) – 5 Category of the LTPP experiments. The objective of the report is to validate the data presented for the SPS-5. While the report validates data availability and completeness of the SPS-5, it provides an insight to the overlay thickness implemented on various LTPP sites. A summary of the overlay thickness implemented at the various LTPP sites are represented in figures 12, 13, and 14, as shown. These histograms for the milling depth and two overlay material thickness levels shown review the distribution of layer thicknesses for all projects. The histograms indicate that while the frequency of use for the 50 mm overlay was about 30 to 35 percent, the thickness of 125 mm ranged between 20 to 25 percent. It also indicates that when milling and overlay were used as a pre-treatment on the pavement sections, the thickness of milling was about 60 mm in most cases. The data represented is extracted from the SPS5_LAYER_THICKNESS of the LTPP database. These thickness variations exhibit typical construction practices. The FHWA report validates these construction overlay thicknesses indicated in the histograms, however, it also states that the data represented in SPS-5 provides impractical tolerances in some cases. *(Von Quintus, et al, 2006).*

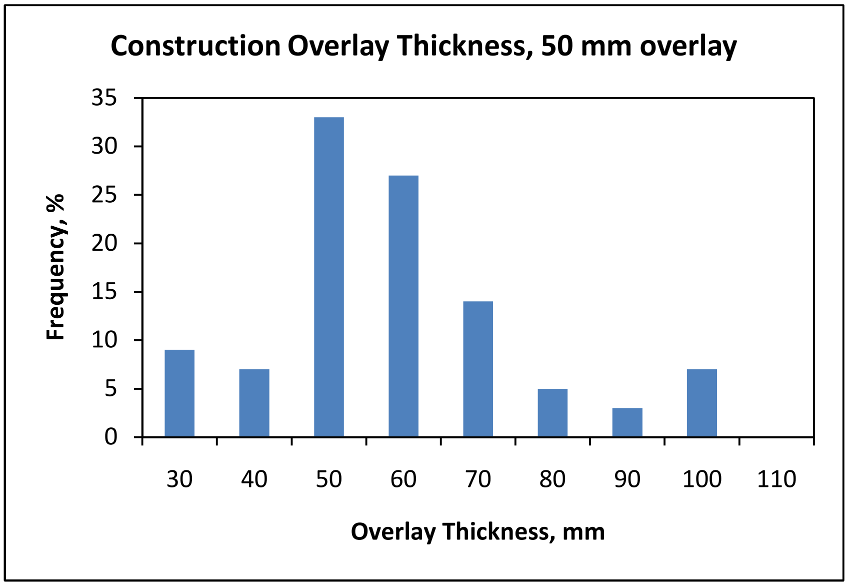

Figure 12. Construction Overlay Thickness, 50 mm overlay

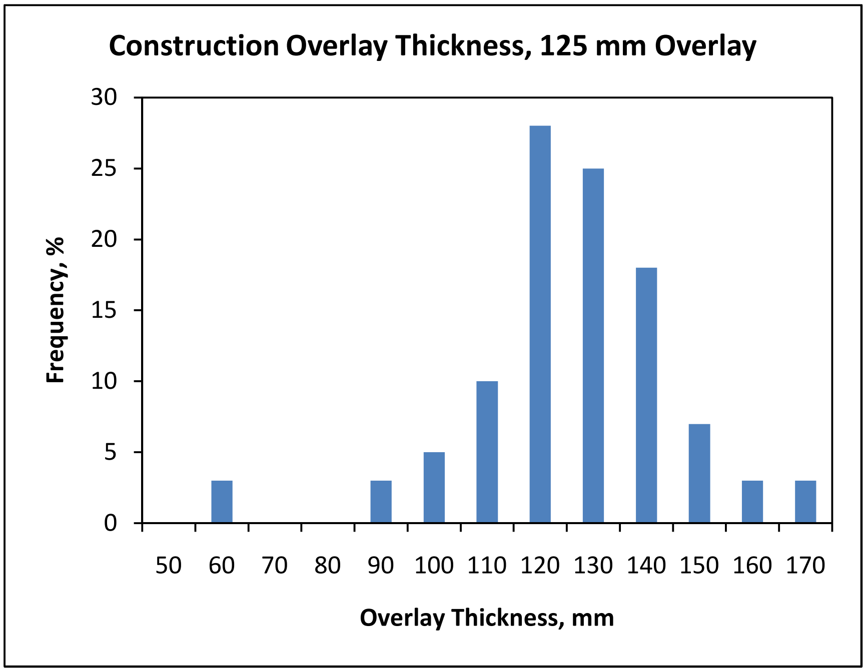

Figure 13. Construction Overlay Thickness, 125 mm overlay

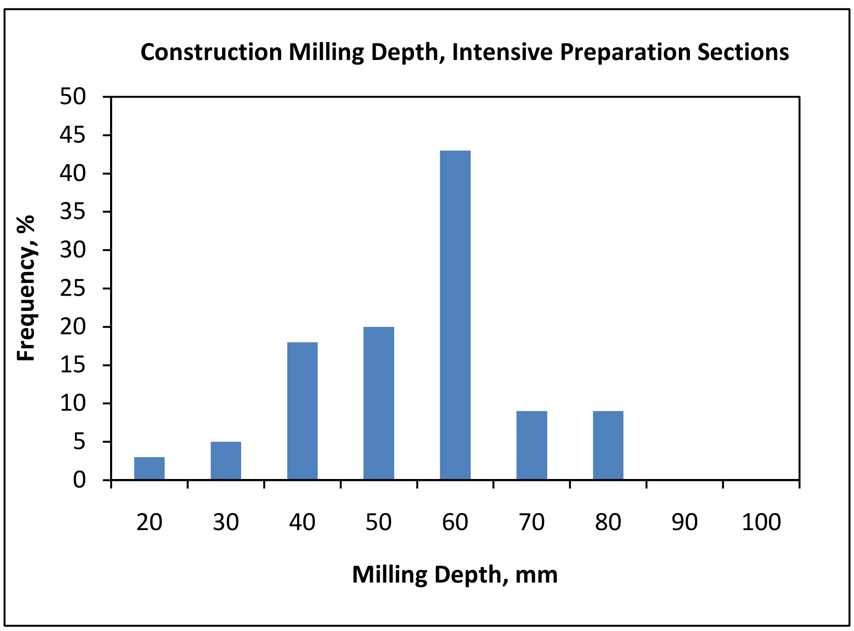

Figure 14. Construction Milling Depth for Intensive Preparation Sections

In conclusion from the LTPP data, it was observed that a variety of factors influence the application of different preventive maintenance techniques on a deteriorated surface. While Chip Seal, Crack Seal, Slurry Seal, and Thin HMA overlay are preferred methods of preventive maintenance for most states. A summary of the analyzed LTPP data is shown in the tables 17 through 19.

Table 17. Summary of LTPP Chip Seal

CHIP SEAL - LONG TERM PAVEMENT PERFORMANCE					
State	Surface Condition	Crack Type	Seal Type	Actual Temperature	Pavement Temperature
Indiana	Normal	Longitudinal	Aggregate Seal	155	86
Maryland	Normal	Transverse	Aggregate Seal	150	99
Michigan	Normal	Edge	Aggregate Seal	165	93
	Normal	Transverse	Aggregate Seal	160	85
Minnesota	Normal	Alligator	Aggregate Seal	-	96
	Normal	Block	Aggregate Seal	178	78
	Normal	Transverse	Aggregate Seal	170	100
New York	Normal	Transverse	Aggregate Seal	160	98
	Slightly Oxidized	Transverse	Aggregate Seal	180	80
	Slightly Oxidized	Transverse	Aggregate Seal	180	70
	Normal	Longitudinal	Aggregate Seal	150	90
Pennsylvania	Flushed only in wheel path	Longitudinal	Aggregate Seal	150	75
Virginia	Flushed only in wheel path	Longitudinal	Aggregate Seal	162	86

Table 18. Summary of LTPP Crack Seal

CRACK SEAL - LONG TERM PAVEMENT PERFORMANCE					
State	Surface Condition	Crack Severity	Crack Type	Pavement Temperature	Seal Thick
Indiana	Normal	Low	Longitudinal	86	0.37
Maryland	Normal	Low	Transverse	99	0.13
	Normal	Low	Transverse	46	0.1
Michigan	Normal	Low	Longitudinal	84	0.4
	Normal	Low	Transverse	-	0.35
	Badly Oxidized	Low	Longitudinal	93	0.37
	Normal	Medium	Edge	106	0.5
Minnesota	Normal	Low	Block	78	0.4
	Normal	Low	Transverse	86	0.4
	Slightly Oxidized	Low	Transverse	100	0.35
	Normal	Low	Alligator	96	0.3
New York	Normal	Low	Transverse	98	0.1
	Badly Oxidized	Medium	Alligator	105	0.13
	Normal	Low	Transverse	90	0.1
	Normal	Low	Transverse	75	0.13
Pennsylvania	Flushed in wheel	Low	Longitudinal	102	0.1
	Flushed in wheel	Low	Longitudinal	80	0.1

Table 19. Summary of LTPP Slurry Seal

SLURRY SEAL - LONG TERM PAVEMENT PERFORMANCE											
State	Crack Type & Severity										Paving Temperature
	Transverse		Alligator		Edge		Block		Longitudinal		
Indiana	✔	Low	-	Low	-	Low	-	Low	-	Low	86
Maryland	✔	Low	-	Low	-	Low	-	Low	-	Low	99
Michigan	✔	Low	✔	Low	✔	Low	-	Low	-	Low	70
Minnesota	✔	Low	✔	Low	-	Low	✔	Low	-	Low	90
New York	✔	Low	✔	Medium	-	Low	-	Low	✔	Low	85
Pennsylvania	-	Low	-	Low	-	Low	-	Low	✔	Low	90

✔ implemented in the state, - no data present

4.0 PENNSYLVANIA DEPARTMENT OF TRANSPORTATION DISTRICT SURVEY

4.1 INTRODUCTION

A survey questionnaire was sent to the 11 districts of Pennsylvania Department of Transportation. This survey questionnaire aimed at understanding the factors influencing preventive maintenance treatments and their application. The main objective of the survey was to highlight the various factors and conditions affecting the preventive maintenance treatments implemented at a district level. The district survey questionnaire was circulated amongst the district representatives during the first week of February 2009.

The results of the survey were compiled in terms of treatment life, pre-overlay repair, traffic conditions, distress conditions, and effectiveness & frequency rating. The responses from the districts indicated that the type of preventive maintenance treatment applied is influenced by these factors as well as previous experience of the district with the treatment. The survey questionnaire used for the district wide survey is attached in Appendix C. The responses received from each district were tabulated and compared to analyze the conditions that contribute to the preventive maintenance treatment. Some of the information each district was asked to provide include the following:

- Treatment(s) used to address pavement distresses (alligator cracking, weathering and raveling, bleeding, and so on) of low, medium, and high severity.

• Expected average service life in years for each preventive maintenance treatment used under low, medium, and high traffic volumes, as defined by each district.

• Typical overlay thickness in inches

The district survey responses are tabulated in Appendix C. Figure 15 represents the various districts of Pennsylvania. Note that District 7 does not exist.

Figure 15. Pennsylvania Department of Transportation Districts

The practices of each district vary with conditions such as temperature, traffic conditions, and geographical location. The practices for preventive maintenance implemented by each district are elaborated in the following sections. The information represented in these sections was obtained in responses to the district level survey questionnaire.

4.2 TRAFFIC CLASSIFICATION

Traffic on interstate pavements can be classified with respect to two parameters, Average Daily Traffic (ADT) or Average Daily Truck Traffic (ADTT). Each district in Pennsylvania was asked to classify the traffic requirements based on these parameters. The classification of traffic levels was sub-divided into low, medium, and high. While most districts represent ADT in numbers and ADTT as a percentage, district 11 classifies ADTT as a number. The following tables represent the ADT and ADTT classification for different districts in Pennsylvania.

Table 20. Pennsylvania District Survey – Traffic Requirements based on ADT

TRAFFIC REQUIREMENTS BASED ON ADT										
Traffic Classification	**Pennsylvania Districts**									
	1-0	**2-0**	**4-0**	**5-0**	**6-0**	**8-0**	**9-0**	**10-0**	**11-0**	**12-0**
Low	10,000	<10,000	<10,000	20,000	-	15,000	5000 to 8000	-	-	1000
Medium	20,000	10,000 - 20,000	10,000 - 20,000	20,000 to 40,000	-	30,000	9000 to 13,000	-	10,000 to 25,000	1000 to 5000
High	40,000	>20,000	>25,000	> 40,000	-	50,000	14,000 to 16,000	30,243	25,000 to 75,000	> 5000

The range of ADT for the different districts is widely distributed. 4 out of 11 districts represent similar ranges, and districts 5 & 8 represent a similar range of ADT levels. However, district 12 comparatively reports a much lower traffic range for classification. A similar pattern is observed for the classification based on ADTT. While 5 out 11 districts represent similar ranges, district 8 represents much lower percentages and district 12 represents much higher percentages. In conclusion, the traffic classification for about 45percent of the districts is similar in nature with exceptions for the other districts.

Table 21. Pennsylvania District Survey – Traffic Requirements based on ADTT

TRAFFIC REQUIREMENTS BASED ON ADTT										
Traffic Classification	**Pennsylvania Districts**									
	1-0	**2-0**	**4-0**	**5-0**	**6-0**	**8-0**	**9-0**	**10-0**	**11-0***	**12-0**
Low	10	<10%	<5	<10%	below 10%	4%	5 to 9 %	-	1300 to 2000	15%
Medium	20	10% - 20%	5 to 20	10 % to 20 %	10 - 20 %	10%	10 to 18 %	-	2000 to 4000	19%
High	45	>25%	>20	> 20 %	over 20 %	20%	19 to 23 %	32%	4000 to 7000	24%

* - indicates the responses given by district was in numbers, compared to ADT requirements, 16% for medium traffic and 9% for high traffic

4.3 TREATMENT TYPE & PAVEMENT DISTRESS

The decision for application of a preventive maintenance treatment on a pavement surface depends on the type of distress and severity of the distress. The survey questionnaire included a section on treatments and distresses which are addressed by each particular treatment.

(a) Crack Seal:

9 out of 11 (81 percent) districts reported the use of crack seal application as a pre-treatment repair and in some cases as a preventive maintenance treatment. The results from the district survey indicated that crack seal is used in most cases to address low to medium severity alligator

cracking, transverse/longitudinal cracking, and edge cracking. District 12 also reported using crack seal application in the presence of high severity potholes. The results indicated that crack seal application was used by 7 out of 11 districts (55 percent) to address medium severity alligator cracking.

Table 22. Pennsylvania District Survey – Crack seal and distress addressed

Preventive Maintenance Treatment and Distresses			
Treatment Type	No of districts	Distress Addressed	
		Distress Type	Severity
Crack Seal	9	Transverse/Longitudinal Cracking	L, M, H
		Alligator Cracking	L, M
		Patching	L
		Edge Cracking	M

L – Low Severity, M – Medium Severity, H – High Severity

(b) Chip Seal:

The district survey responses indicated that the use of chip seal application is not a very popular preventive maintenance treatment. Although the literature review indicated an extensive use of chip sealing at high traffic roadways, the district survey results were contrary. The districts 8, 9, and 12 reported the use of chip seal. Chip seal application was mainly implemented on pavements exhibiting low to medium severity alligator cracking, weathering/raveling, transverse/longitudinal cracking, and edge cracking. District 8 applied chip seal to address low to high severity potholes. These results of treatment application were compared with the traffic ranges for these districts. The comparison indicated that chip sealing is used to address distresses in areas with low to medium ADT. While district 12 reported low range of ADT compared to the major districts, districts 8 and 9 reported a medium range of ADT.

Table 23. Pennsylvania District Survey – Chip seal and distress addressed

Preventive Maintenance Treatment and Distresses			
Treatment Type	No of districts	Distress Addressed	
		Distress Type	Severity
Chip Seal	3	Alligator Cracking	L
		Potholes	L, M, H
		Weathering/Raveling	L, M
		Transverse/Longitudinal	L
		Edge Cracking	L, M

L – Low Severity, M – Medium Severity, H – High Severity

(c) Sand Seal:

Many districts do not report the use of sand seal as a preventive maintenance treatment. However, district 9 and 10 reported the use of this treatment to address low to medium severity bleeding. The effective service life of sand seal application is varied between both the districts.

Table 24. Pennsylvania District Survey – Sand seal and distress addressed

Preventive Maintenance Treatment and Distresses			
Treatment Type	No of districts	Distress Addressed	
		Distress Type	Severity
Sand Seal	2	Bleeding	L, M

L – Low Severity, M – Medium Severity, H – High Severity

(d) Microsurfacing:

Microsurfacing is reported by 5 out of 11 districts (45 percent) as a preventive maintenance treatment. The use of microsurfacing is reported for a wide range of distresses. For districts with a high range of traffic classification (district 1 and 3) microsurfacing addressed low to medium severity distresses such as alligator cracking, stripping, weathering/raveling, and transverse/longitudinal cracking. However, districts 10 and 11 reported using microsurfacing for medium to high severity bleeding. District 12 reported the application of microsurfacing for rutted pavements.

Table 25. Pennsylvania District Survey – Microsurfacing and distress addressed

Preventive Maintenance Treatment and Distresses			
Treatment Type	No of districts	Distress Addressed	
		Distress Type	Severity
Microsurfacing	5	Alligator Cracking	L, M
		Stripping	L, M
		Weathering/Raveling	M
		Transverse/Longitudinal	M
		Bleeding	M, H
		Longitudinal joint cracking, and Rutting	M

L – Low Severity, M – Medium Severity, H – High Severity

(e) HMA overlay:

The review of the district responses indicated that all the districts in Pennsylvania considered greater than 2" HMA overlay as a treatment to address most high severity distresses. In addition, most districts also reported the use of less than 2" HMA overlay as a preventive maintenance treatment for almost all medium severity distresses. The results indicate that HMA overlay is a widely used preventive maintenance technique to address all kinds of distresses over a wide range of traffic classifications. 4 out of 11 districts indicated the use of HMA overlays greater than 2", it is used to address a range of high severity distresses such as alligator cracking, weathering/raveling, rutting, transverse/longitudinal cracking, corrugations, patching, and stripping.

Table 26. Pennsylvania District Survey – Thin HMA Overlay and distress addressed

Preventive Maintenance Treatment and Distresses			
Treatment Type	No of districts	Distress Addressed	
		Distress Type	Severity
Thin HMA Overlay (<2" thick)	6	Alligator Cracking	L, M, H
		Stripping	M
		Weathering/Raveling	M, H
		Transverse/Longitudinal	M, H
		Rutting	M
		Potholes	M
		Corrugations	M
		Bleeding	M, H
		Patching	M

L – Low Severity, M – Medium Severity, H – High Severity

Table 27. Pennsylvania District Survey – Thick HMA Overlay and distress addressed

Preventive Maintenance Treatment and Distresses			
Treatment Type	No of districts	Distress Addressed	
		Distress Type	Severity
Thick HMA Overlay (>2" thick)	4	Corrugations	M, H
		Stripping	L, M
		Weathering/Raveling	M, H
		Potholes	H
		Edge Cracking	H
		Transverse/Longitudinal	M
		Bleeding	M, H

L – Low Severity, M – Medium Severity, H – High Severity

(f) Polymer modified HMA overlay:

6 out of 11 districts report the use of polymer modified HMA overlay to prevent high severity distresses such as, alligator cracking, weathering/raveling, transverse/longitudinal cracking, stripping, corrugation, rutting, potholes, patching, and edge cracking. District 5 and 10 however reported using this treatment to address high severity rutting.

Table 28. Pennsylvania District Survey – Polymer modified HMA overlay and distress addressed

Preventive Maintenance Treatment and Distresses			
Treatment Type	No of districts	Distress Addressed	
		Distress Type	Severity
Polymer modified HMA overlay	6	Alligator Cracking	M, H
		Stripping	M
		Weathering/Raveling	M, H
		Transverse/Longitudinal	M, H
		Rutting	H
		Potholes	H
		Corrugations	M
		Bleeding	M, H
		Patching	H

L – Low Severity, M – Medium Severity, H – High Severity

(g) Milling and overlay:

An analysis of the district responses indicated that most Penn DOT districts use milling and overlay to address medium to high severity distresses of many kinds. 9 out of 11 (82 percent) of the districts indicate implementing this treatment to prevent rutting, weathering/raveling, corrugation, alligator cracking, and transverse/longitudinal cracking. Some districts also report using this method to address high severity stripping, and bleeding. Interestingly, district 3 reports the use of mill and overlay to prevent the occurrence of high severity water seepage.

(h) Cold or Mechanized patch, or base repair:

This type of treatment was most commonly used to treat potholes of medium severity by districts 1, 4, 5, 6, 10, and 12. However, district 10 also reported using base repair to address medium severity alligator cracking.

Table 29. Pennsylvania District Survey – Milling and Overlay and distress addressed

Preventive Maintenance Treatment and Distresses			
Treatment Type	No of districts	Distress Addressed	
		Distress Type	Severity
Milling and Overlay	9	Alligator Cracking	H
		Rutting	M, H
		Weathering/Raveling	H
		Transverse/Longitudinal	M, H
		Rutting	H
		Potholes	H
		Corrugations	M, H
		Bleeding	M, H
		Patching	H

L – Low Severity, M – Medium Severity, H – High Severity

In summary, most districts implement thin HMA overlay's in case of the pavement over all ranges of traffic for almost all distresses such as alligator cracking, weathering and cracking, rutting, potholes, corrugations, patching, bleeding, and stripping. Polymer modified HMA overlays are implemented for most of the distresses like cracking, rutting, stripping, weathering and raveling, and potholes. While milling and overlay is applied for treatments such as weathering and raveling, rutting, corrugations, and bleeding. Crack sealing on the other hand is applied to the pavements exhibiting transverse & longitudinal cracking, alligator cracking, and edge cracking. However, it was observed that microsurfacing was applied to pavements with distresses such as alligator cracking, stripping, bleeding, and rutting.

Furthermore, the associated treatment selection matrices in the Pavement Policy Manual, Publication 242, suggest treatments for different distresses (fatigue cracking, transverse cracking, weathering/raveling, and so on) of low, medium, and high severity. In most cases, low severity distresses are not recommended to be treated. Only in the case of low severity miscellaneous cracking is resurfacing suggested at 30 percent of the section's length is cracked. In general, the first suggested treatment is patching with mill and overlay being used to address extensive deterioration. The treatments used to address low, medium, and high severity distresses can be represented in percentages of treatment use.

The percentages in the figures are obtained as a weighted average. For example, if crack seal is used as a treatment by 2 out of 11 districts, the ratio of treatment use is 0.18 (2/11), this number was divided by the number of repetitions to avoid overlap in treatment use giving a number 0.06. This number was then used to obtain a weighted average of crack seal use in the district for low severity distresses. This method of analyzing treatment use is approximate; however, it exhibits a close percentage of treatment use for the different levels of severity for distresses. The table below explains the calculations.

Table 30. Pennsylvania District Survey – Milling and Overlay and distress addressed

Ratio of treatment use			Weighted average			Weighted Percentage - Low Severity
Low	Medium	High	Low	Medium	High	weighted average / (sum of total weighted averages of all low severity treatments)
0.18	0.54	0.45	0.06	0.18	0.15	

A similar set of calculations was used to develop the weighted percentages of medium to high severity distress use. The following figures represent the treatment application by Penn DOT districts for low, medium, and high severity distresses.

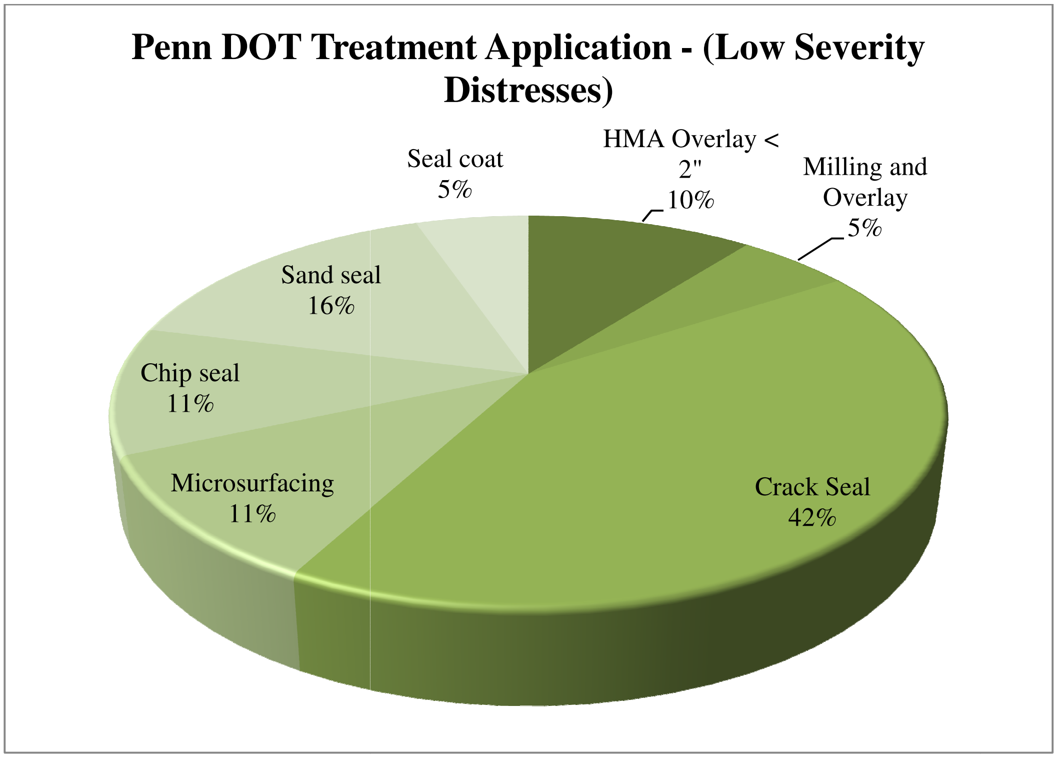

Figure 16. Penn DOT districts treatment use for low severity distresses

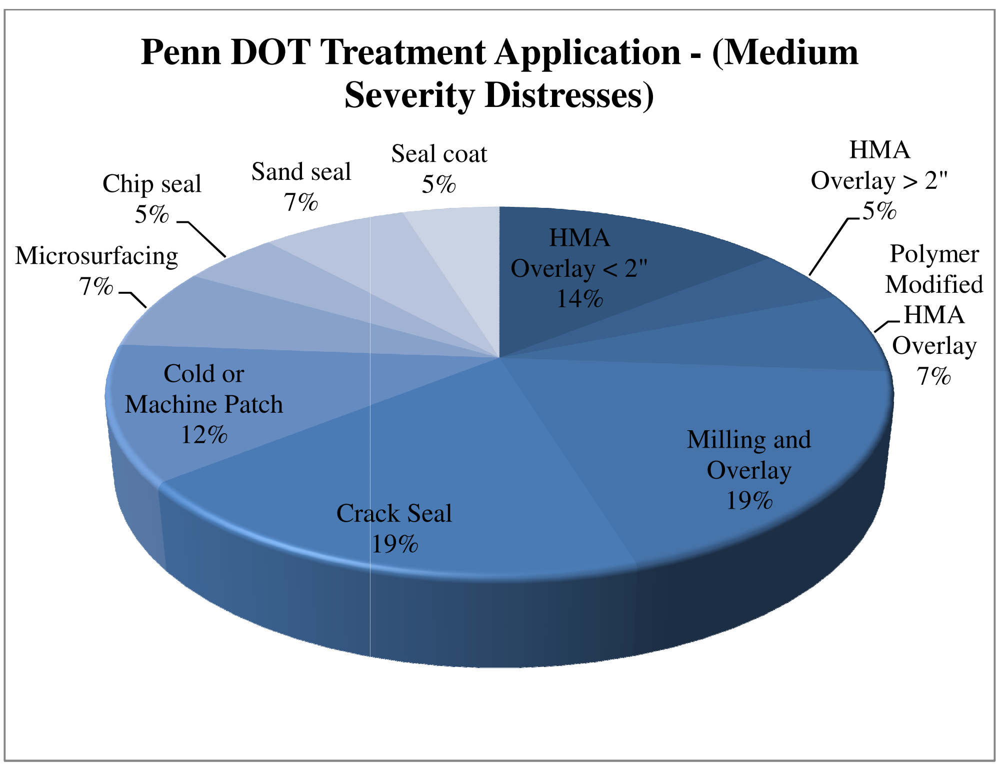

Figure 17. Penn DOT districts treatment use for medium severity distresses

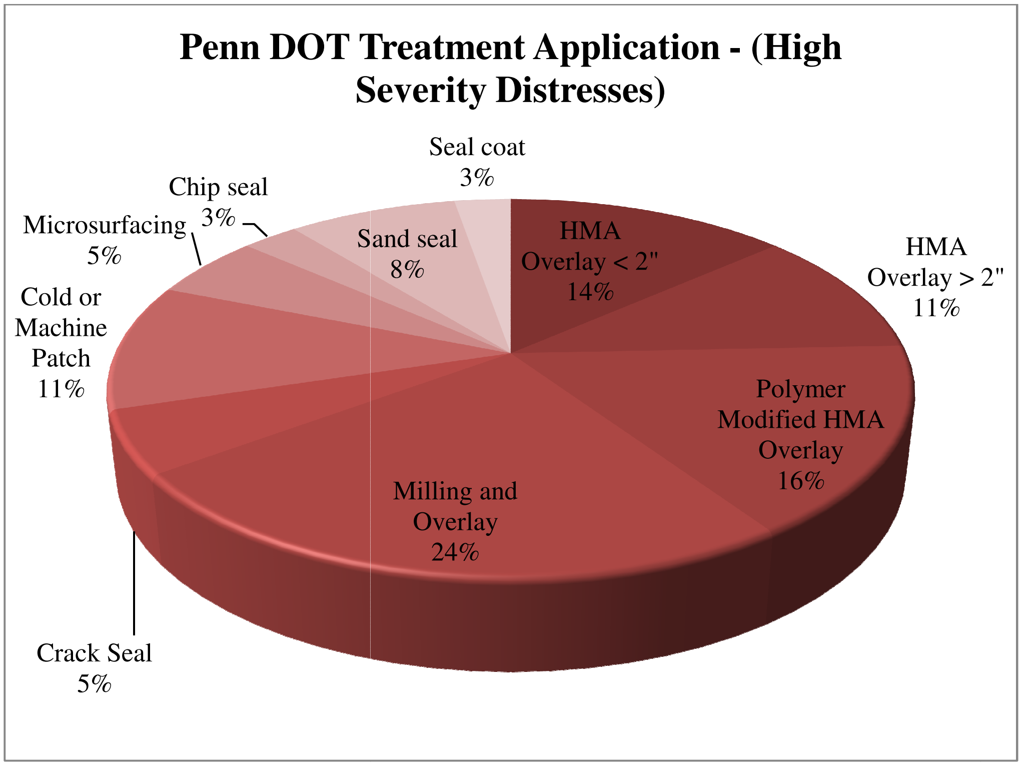

Figure 18. Penn DOT districts treatment use for high severity distresses

4.4 TREATMENT LIFE

The treatment life of a pavement surface is influenced by the type of preventive maintenance technique implemented on the pavement. The traffic on a pavement stretch can be classified under three different ranges low traffic, medium traffic, and high traffic. The classification of traffic is based on the Average Daily Traffic and the Average Daily Truck Traffic. Based on the survey responses, most districts report a similar service life in years.

4.4.1 Pre-Treatment Repair

(a) Crack Seal:

The pre-treatment repair most commonly used by the districts in Pennsylvania is crack seal application. The service life extension of crack seal application is about 3 to 5 years. Most Penn DOT districts (10 out of 11) report the use of crack sealing as a pre-treatment repair for low to medium severity distresses such as transverse/longitudinal cracking, alligator cracking, and edge cracking on high traffic pavements. The survey responses also indicate that while some districts experienced a higher service life (up to 8 years) for crack sealing on low to medium traffic surfaces, about 63% of the districts (7 out of 11) exhibit a service life extension of 3 to 5 years. However, district 12 reported that the life of a crack seal on high traffic roads is only 2 years although the traffic levels for district 12 are much lower compared to other Penn DOT districts. The range of service life extensions are within the expected life of 2 to 6 years as stated by Penn DOT.

4.4.2 Preventive Maintenance

(a) Chip Seal:

Chip seals typically last about 3 to 5 years for most districts except in District 12, which reports an expected life of about 7 to 10 years. The extended performance of the chip seals in District 12 is due to the low range of traffic, which at 1,000 to 5,000 ADT is half that of other districts.

Table 31. Pennsylvania District Survey – Crack Seal Treatment Life

Treatment Type	Traffic Level	Pennsylvania Districts										
		1-0	2-0	3-0	4-0	5-0	6-0	8-0	9-0	10-0	11-0	12-0
Crack Seal	Low	8	n/a	3 - 5	3 – 5	3 -5	n/a	7	5 *	3	5*	5
	Medium	6	n/a	3 - 5	3 - 5	3 - 5	n/a	7	5	3	5	3
	High	5	n/a	3 - 5	3 - 5	5	3 - 5	3 - 5	5	3	5	2

n/a – not applied

(b) Sand Seal:

Sand sealing application in Districts 3 and 10 last up to 3 months, while in Districts 9 and 12, 3 years is more typical. On the other hand, there are instances where a treatment in one district has performed significantly better or worse compared to another.

(c) Microsurfacing:

Microsurfacing, in general has an expected service life of 4 to 7 years, and is typically performing for at least 5 years in Pennsylvania, even up to 10 years on low-traffic volume (less than 15,000 ADT) roads in one district. However, although district 12 has a lower traffic, microsurfacing does not seem to perform much better than the other districts.

(d) HMA Overlay:

A majority of districts reported the service life of HMA Overlay (less than 2 inches & greater than 2 inches) increase the service life of the pavement by about 8 to 10 years. Although district 8 and 13 indicate that an HMA overlay greater than 2 inches provides an extension of up to 13 years in some cases.

(e) Polymer modified HMA overlay:

Polymer modified HMA overlay reportedly also increases service life by about 8 to 10 years for most of the districts. In district 9, this treatment provides 12 years on high traffic pavements. However, it can be observed that the traffic levels for district 9 are relatively lesser in range compared to the other districts. A summary of the responses of the district survey for preventive maintenance treatment service life is shown in the Table 32.

4.4.3 Rehabilitation

In case of cold in-place recycling, an average service life of 5 years was reported in District 4 on roadways with less than 10,000 ADT compared to a minimum service life of 15 years in District 12 on roadways with less than 1,000 ADT. However, other districts do not report using this rehabilitation procedure.

Table 32. Pennsylvania District Survey – Preventive Maintenance Treatment - Treatment Life

Treatment Type	Traffic Level	Pennsylvania Districts										
		1-0	2-0	3-0	4-0	5-0	6-0	8-0	9-0	10-0	11-0	12-0
Microsurfacing	Low	7	n/a	5	5 - 7 *	n/a	n/a	8 - 10	n/a	3 – 5	8 *	5
	Medium	6	n/a	5	5 - 7 *	n/a	n/a	8	n/a	3 – 5	n/a	3
	High	5	n/a	5	5 - 7 *	n/a	8	4 - 6	n/a	1 – 3	8	n/a
Polymer Modified HMA Overlay (2" Depth)	Low	11	n/a	n/a	n/a	8 - 10	n/a	n/a	n/a	n/a	10	10
	Medium	10	n/a	n/a	n/a	8 - 10	n/a	9 – 11	n/a	n/a	10	5 – 7
	High	10	n/a	10	n/a	8 - 10	10 [a]	9 – 11	12 **	5 - 10	8	10-15
HMA Overlay (less than 2 inches)	Low	11	n/a	10	n/a	8 - 10	n/a	10-12	8 **	n/a	8	10-15
	Medium	10	n/a	10	n/a	8 - 10	n/a	8 - 10	n/a	n/a	8	7 - 10
	High	10	n/a	10	n/a	8 - 10	10 [a]	8 - 10	n/a	n/a	6	7 - 10
HMA Overlay (greater than 2 inches)	Low	11 (min.)	10 (min.)	10	n/a	8 -10	n/a	15	10 ** **	5 - 10	8	10-15
	Medium	10	10 (min.)	10	n/a	8 - 10	n/a	13-15	10 **	5 - 10	8	7 - 10
	High	10	10 (min.)	10	n/a	8 - 10	10 [a]	10-13	10 **	5 - 10	6	7 - 10
Sand Sealing	Low	n/a	n/a	30-60 [d]	n/a	n/a	n/a	n/a	3 *	0 - 3 [m]	n/a	3
	Medium	n/a	n/a	30-60 [d]	n/a	n/a	n/a	n/a	3	0 - 3 [m]	n/a	n/a
	High	n/a	n/a	30-60 [d]	n/a	n/a	n/a	n/a	3	0 - 3 [m]	n/a	n/a
Chip Seal	Low	n/a	n/a	n/a	3 - 5	n/a	n/a	3 - 5 *	3 *	4	n/a	5
	Medium	n/a	n/a	n/a	3 - 5	n/a	n/a	3 - 5 *	3	3 - 4	n/a	7 - 10
	High	n/a	n/a	n/a	3 - 5	n/a	n/a	n/a	3	3 - 4	n/a	n/a

* - Based on ADT

** - Based on ADT/ADTT

[a] - PG 76 -22

[m] - Months

[d] – Days

n/a – Not Applied

4.4.4 Other Treatments

(a) Open graded friction courses:

Open graded friction courses were reported by districts 1 and 12 to extend the service life considerably over low to medium traffic. The reported ADT for district 12 is lower than most other districts and thus, this treatment exhibit greater life extension for medium trafficked roads. In general, the service life extension is about 9 years. Interestingly, not all treatments perform better in District 12, where there is significantly lower traffic volumes reported. Open-graded friction course has an average service life of 6 years in District 12, nearly half of that expected in District 1.

(b) Rubberized asphalt chip seal:

Rubberized asphalt chip seal is also commonly used in districts 8, 9, and 12 extending the service life by about 4 to 8 years on an average.

Table 33. Pennsylvania District Survey – Preventive Maintenance Treatment (Other) - Treatment Life

Treatment Type	Traffic Level	Pennsylvania Districts			
		1-0	8-0	10-0	12-0
Open Graded Friction Course	Low	10	n/a	n/a	5 – 7
	Medium	9	n/a	n/a	10
	High	8	n/a	n/a	n/a
Rubberized Asphalt Chip Seal	Low	n/a	6 - 8 *	4	5
	Medium	n/a	6 - 8 *	4	7 -10

n/a – Not Applied

Owing to the varied traffic and geographical conditions of district 12, treatments such as fog seal, double chip seal, and slurry seal were reported to provide considerable service life extension. The table below enumerates the life extension in years. District 3 also reported the use of Stone matrix asphalt treatment providing a considerable life extension of 15 years.

Table 34. Pennsylvania District Survey – Treatment Life of Preventive Maintenance Treatments (Others)

Treatment Type	Traffic Level	District No.	Treatment Life (in years)
Fog Seal	Low	12	5
	Medium		3
	High		2
Double Chip Seal	Low	12	5 - 7
	Medium		10
	High		-
Stone Matrix Asphalt	Low	3	15
	Medium		15
	High		15
Slurry Seal	Low	12	3
	Medium		5
	High		-

Based on the traffic classification, the treatment use pattern for some of the most common preventive maintenance treatments can be summarized using the following figures. The figure indicates that for interstate pavements or pavements with high traffic, the most widely used treatments are thin HMA overlays, polymer modified HMA overlays, microsurfacing, and crack seal. Whereas, treatments such as sand seal and chip seal are used by a smaller percentage of districts. Figure 19 represented below are based on the weighted average percentage of treatment use for the Penn DOT districts for pavement distresses.

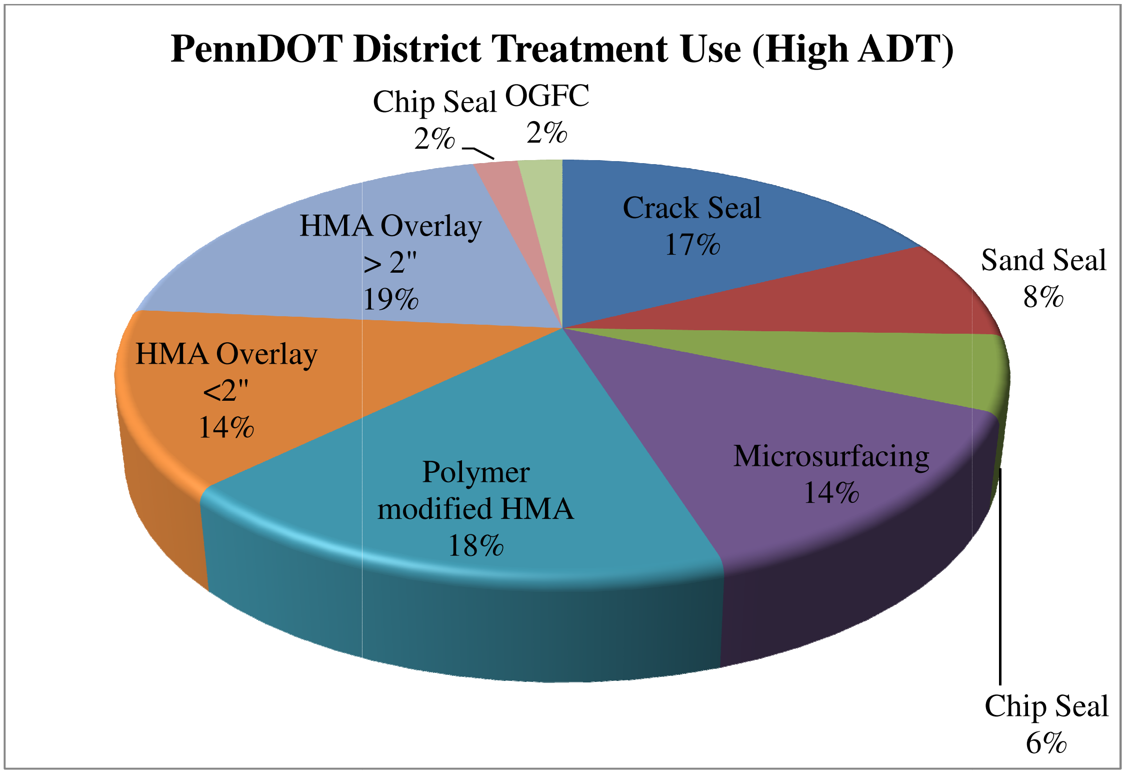

Figure 19. PennDOT districts treatment use pattern for High ADT pavements

4.5 PRE-OVERLAY REPAIR

The pre-overlay repair methods applied by the districts are crack seal, chip seal, partial depth patching, full depth patching, milling, and joint sealing. While most of these pre-treatments are performed on pavements exhibiting cracking, weathering and raveling and stripping, different districts have reported their use in the presence of various other distress conditions.

(a) Crack Seal:

The use of crack seal is one of the most popular forms of pre-overlay repair for preventive maintenance. The survey indicated that crack seal is used by most districts in the presence of alligator cracking, transverse/longitudinal cracking, edge cracking, and weathering/raveling.

(b) Joint Sealing:

Joint sealing in most districts is used as an effective form of pre-overlay repair for transverse/longitudinal cracking, edge cracking, and pothole repair. Some districts report its use for patching and rutting.

(c) Chip Seal:

Although chip sealing was observed to be an effective preventive maintenance treatment, some districts reported its use as a pre-overlay repair method. It is implemented on distresses such as, edge cracking, alligator cracking, transverse/longitudinal cracking, and weathering/raveling.

(d) Partial and Full Depth Patching:

Partial and full depth patching were reported by most districts to be effective in the presence of distresses such as, alligator cracking, patching, potholes, transverse/longitudinal cracking, and rutting. The service life extension by these treatments were not present in the responses, however, the use of these methods was reported by the various districts.

(e) Milling:

Milling and overlay was reported by most of the districts as a pre-overlay repair for most pavement distresses. The pavement distresses such as alligator cracking, transverse/longitudinal cracking, rutting, corrugations, bleeding, weathering, stripping, and patching are addressed by milling before the placement of overlay.

(f) Microsurfacing:

District 3 reported that microsurfacing is used as a pre-overlay repair to address alligator cracking, weathering/raveling, and stripping. However, district 10 reported the use of this method as a pre-overlay repair to increase the skid resistance of the pavement surface.

(g) Leveling Course:

Another common method of pre-overlay repair reported in use by most of the Penn DOT districts is the leveling course. The application of a leveling course was seen to be in the case of almost all the distresses.

A summary of the survey responses of pre-overlay repair for preventive maintenance at the various districts is indicated in the Table 35.

Table 35. Pennsylvania District Survey – Pre-overlay Repair of Preventive Maintenance Treatments

PREOVERLAY REPAIR FOR PREVENTIVE MAINTENANCE TREATMENTS											
Treatment Type	Pennsylvania Districts										
	1-0	2-0	3-0	4-0	5-0	6-0	8-0	9-0	10-0	11-0	12-0
Crack Seal	EC	-	AC, TL, EC	TL	AC, TL, EC	-	-	AC, TL, EC	AC, WR, TL, EC	-	AC, WR, TL, EC
Chip Seal	-	-	B	-	-	-	-	AC, WR, TL, EC, S	AC, WR	-	WR, P, Pa
Partial depth Patch	AC, P	-	AC, TL, R, P, EC, WS	P, EC	WR, TL, R, P, C, Pa, EC, S	TL, R, P, C	P, Pa	AC, WR, TL, C, ED, S, P, Pa, B	AC, P, Pa	TL, P, EC	WR, TL, C, Pa, B, EC
Full Depth Patch	AC, TL, Pa	-	TL, R, P, WS	AC, Pa	WR, TL, R, P, C, Pa, EC, S	TL, R, C	AC, TL, R, Pa, EC, S	TL, P, Pa, EC	WR, P, Pa	P, EC	TL, R
Milling	WR, R, B, EC, S	-	AC, WR, TL, R, C, B, M, WS	AC, R, C, Pa	AC, TL, WR, R, C, S	AC, WR, TL, R, P, C, Pa	WR, R, S	R, C	R, C	AC, WR, TL, R, P, C, Pa, B, EC, S	AC, WR, R, C, Pa, B, EC, S
Leveling Course	AC, WR, R, B, S	All	AC, WR,TL, R, C, WS	B	R, C, Pa, B, S	AC, WR, TL, R, P, C, Pa	AC, WR, TL, C, P, Pa, B, EC	R, C, P, Pa	R,C, S	-	AC, R, P, C, Pa, B, S
Microsurfacing	-	-	AC, WR, S	-	-	-	-	-	SKID	-	-
Joint Sealing	-	-	TL, R, P, EC	EC	AC, TL	-	-	TL, P, Pa, EC	TL, EC	-	TL

*** AC – Alligator Cracking, B – Bleeding, C – Corrugations, EC – Edge Cracking, M – Milling, P – Potholes, Pa – Patching, R- Rutting, S – Stripping, TL – Transverse & Longitudinal Cracking, WR – Weathering & Raveling, WS – Water Seepage

4.6 TREATMENT THICKNESS

The treatment thickness is influenced by the type of distress and the conditions of traffic.

4.6.1 Pre-Treatment Repair

(a) Crack Seal:

Although crack seal is a common pre-treatment repair as reported by the districts, not all districts specify a thickness for its application. District 3 reports using 0.25 inch deep crack seal application followed by microsurfacing after about 1 to 2 years.

(b) Leveling Course:

While most districts reported the use of leveling course as a common method of pre-overlay repair only district 9 specified a 1 inch thickness of this pre-treatment.

4.6.2 Preventive Maintenance Treatment

(a) Microsurfacing:

Only two districts 11 and 3 indicated the thickness of microsurfacing 0.5 and 1.5 inches respectively. The use of microsurfacing was however represented by the districts in terms of service life and distress conditions. The frequency and efficiency of microsurfacing is discussed in the following sections.

(b) HMA Overlay:

Most of the districts indicated that the thickness of thin HMA overlay is about 1.5 inches. District 4-0 however uses an inch of thin HMA overlay for patching and bleeding. HMA overlay's greater than 2 inches are also implemented in most of the districts. A majority of the districts indicated the use of 2 inches of polymer modified HMA overlay. While District 3-0 uses a 1.5 in thick overlay for medium severity distress, a 4 in overlay is used in case of high severity distress.

(c) Polymer modified HMA overlay:

District 5-0 reported the use of 1.5 to 2 inch thick polymer modified overlay when the surface was milled.

(d) Milling and overlay:

While most of the districts reported a thickness of 1.5 to 2 inches for milling and overlay, in case of high severity distress or presence of water seepage the treatment applied is about 4 inches thick. Milling and overlay was reported as an effective pre-overlay repair treatment for most of the districts and it can be concluded that the service life by about 3 to 5 years.

The Publication 242 summarizes that the HMA wearing course overlays with a thickness less than 1.5 in cannot be placed on interstates. The district practices findings for thickness of treatments validates this requirement for Penn DOT. A summary of the survey is represented in the Table 36.

Table 36. Pennsylvania District Survey – Treatment Thickness of Preventive Maintenance Treatments

TREATMENT THICKNESS									
Treatment Types	Pennsylvania Districts								
	1-0	3-0	4-0	5-0	8-0	9-0	10-0	11-0	12-0
HMA Overlay (< 2 in)	-	1.5"	1" , 1.5" [a]	1.5"	< 2"	-	1.5"	-	< 2"
HMA Overlay (> 2 in)	-	-	-	-	1.5 - 2"	2"	-	> 2"	2"
Leveling Course	-	-	-	-	-	1"	-	-	-
Polymer Modified HMA Overlay	2"	1.5" [MS] ; 4" [HS]	-	1.5"- 2" [e]	-	2"	-	2 - 4.5"	-
Milling and Overlay	-	1.5" , >1.5" [HS], 4" [b]	1.5"	2"	2"	2"	4"	-	4"
Crack Seal	-	0.25" [c]	-	-	-	-	-	-	-
Cold or Mechanized Patch	-	1.5" [d]	-	-	-	-	-	-	-
Microsurfacing	-	1.5"	-	-	-	-	-	5/8 "	-

[a] – for patching, bleeding
[MS] – medium severity
[HS] – high severity
[b] – Water seepage
[c] – Microsurfacing after 1 to 2 years
[d] – Or full depth repair
[e] – Milling

4.7 APPLICATION TEMPERATURE

The application of a treatment also considers the temperature at which the preventive maintenance treatment is implemented on a pavement surface. Each district reports a range of temperature with respect to the type of treatment applied on the surface. While most districts reported the use of thin HMA overlay and polymer modified HMA overlays were applied at a temperature range of 40 to 50°F. However, certain districts exhibited exceptions to the general temperature ranges. The districts reported application of crack sealing between the ranges of 40 to 90°F.

The map of Penn DOT districts represents that, 1 and 12, along with 10 and 11, cover the western portion of the state, occupying the north- and southwest corners, respectively. However, District 1 is predominantly at a higher elevation than District 12 (1,200 to 1,800 ft as opposed to 600 to 1,200 ft), and the annual precipitation is comparable for both districts, although a portion of District 12 does experience 10 in less on average *(Cole 2009; National Atlas 2008)*. The district survey indicated that the range of minimum and maximum temperatures is widely distributed. District 1 has a highest pavement temperature variation as compared to most other districts. While most districts report a similar difference in pavement temperature, districts 8 and 11 show comparatively low differences. Districts 9 and 12 are similar in terms of pavement temperature. A summary of the pavement temperature and the application temperatures is shown in the table below.

In conclusion, the results of the survey indicate that while district 12 has a lower range of temperature for treatment application, district 1 has a slightly higher temperature range considering its altitude. With respect to districts 3, 9, and 10 the temperature ranges for application of similar preventive maintenance treatments is much higher due to the a higher variation in temperature in these districts as compared to the others. Majority of the other districts exhibit similar temperature ranges for the application of preventive maintenance treatments.

Table 37. Pennsylvania District Survey – Application and Pavement Temperature of Preventive Maintenance Treatments

APPLICATION AND PAVEMENT TEMPERATURE (˚F)										
Treatment Type	**Pennsylvania Districts**									
	1-0	**3-0**	**4-0**	**5-0A**	**6-0**	**8-0**	**9-0**	**10-0**	**11-0**	**12-0**
Minimum	0	18	5	20	10	44.4	20	19	41	39
Maximum	99	83	95	85	98	62.7	85	82	60	63
Crack Seal	40 - 90	-	375 - 400	-	-	40 - 90	-	-	40	40
	40 - 90	40 - 60	40 - 90	40 - 90	-	40 - 90	40 - 90	40	50	40
Chip Seal		-	140 - 175	-	-	60	140 - 175	140 - 175	-	60
	-	-	60 - 90	-	-	60	60	60	-	60
Double Chip Seal	-	-	140 - 175	-	-	60	-	140 - 175	-	60
	-	-	60 - 90	-	-	60	-	60	-	60
Slurry Seal	-	-	-	-	-	50	-	-		40 - 90
	-	-	-	-	-	50	-	-	-	40 - 90
Rubberized Asphalt Chip Seal	-	-	-	-	-	60	-	-	-	40
	-	-	-	-	-	60	-	-	-	40
Micosurfacing	50 -90	-	-	-	-	-	-	70 - 150	-	40
	50 - 90	50	-	-	-	-	-	50	-	40
Open Graded Friction Course	50 - 90	-	-	-	-	-	-	-	-	40
	50 - 90	-	-	-	-	-	-	-	-	40
Cold In place Recycling	-	-	-	-	-	60	-	-	-	45
	-	-	-	-	-	60	-	45	-	45
Stone Matrix Asphalt	-	285 - 330	-	-	-	-	-	-	-	-
	-	>= 50	-	-	-	-	-	-	-	
Polymer Modified HMA Overlay	40 - 90	285 - 330	-	-	a	40 - 50	285 - 330	285 - 330	40	40
	40 - 90	>= 40	-	> 40	-	40 - 50	40	40	50	40
HMA Overlay (less than 2 inches)	-	265 - 320	-	-	-	40 - 50	265 - 320	285 - 330	40	40
	-	>= 40	-	> 40	-	40 - 50	40	40	50	40
HMA Overlay (greater than 2 inches)	40 - 90	265 - 320 F	-	-	-	40 - 50	265 - 320	285 - 330	40	40
	40 - 90	>= 40	-	> 40	-	40 - 50	40	40	50	40

a - PUB 408, 409.3 (b)

4.8 SERVICEABILITY CONDITIONS

The serviceability of a pavement is classified based on pavement serviceability rating (PSR), international roughness index (IRI) and pavement condition index (PCR). The various districts reported the serviceability based on IRI. Most districts reported an overall IRI rating of above 100 for the use of different treatments.

Table 38. Pennsylvania District Survey – Serviceability Requirements of Preventive Maintenance Treatments

Treatment Types	**Penn DOT District Number (International Roughness Index – IRI)**							
	1-0	**2-0**	**5-0**	**6-0**	**8-0**	**9-0**	**11-0**	**12-0**
Polymer Modified HMA Overlay	71 - 150	-	>100	a	120	> 121	≥ 130, Overall ≤ 75	> 100
Crack Sealing	-	-	-	-	115	-	-	-
Microsurfacing	-	-	-	-	140	-	-	-
HMA Overlay(< 2”)	-	-	>100	-	115	101 - 120	≥ 130, Overall ≤ 75	> 100
HMA Overlay(> 2”)	≥ 101	80 - 100	>100	-	140	> 121	≥ 130, Overall ≤ 75	> 100

a - as per pavement distress

In summary, it can be concluded from the survey responses that while most districts apply HMA overlays at an IRI greater than 100, the range is greater than 120 for districts 8, 9, and 11. This can be because of higher temperature variations in these districts in comparison to the other districts. While the rating for cracking sealing and microsurfacing are not clearly well defined based on IRI, district 8 has a range of IRI of 115 for crack sealing, and 140 for microsurfacing. However, the variation in the ranges for polymer modified HMA overlay is greatly scattered.

The results of the IRI rating for each treatment can also be interpreted in relation to the distress types present on the pavement. Medium severity distresses such as alligator cracking, transverse/longitudinal cracking, edge cracking, stripping, potholes, and corrugations are most commonly addressed by treatments such as crack sealing, thin HMA overlays, and microsurfacing. It can be observed that the IRI rating for the pavements are relative to the presence of these distresses.

4.9 EFFECTIVENESS AND FREQUENCY RATING

The districts were asked to rate the treatment types based on their effectiveness and frequency of application. The effectiveness rating provided by the districts was based on the service life extension provided by the various treatments implemented on the bituminous surface. The frequency of application was rated based on the implementation of the preventive maintenance treatments. The rating of efficiency and frequency for the preventive maintenance treatments was made on a scale of 1 to 5. A list of efficient and frequently used treatments was obtained based on the preventive maintenance treatment.

Based on effectiveness ranking the top list of treatments used are:

- Crack seal
- Thin HMA overlay
- Chip seal
- Microsurfacing

Based on the frequency ranking the top treatments used are:

- Microsurfacing

- Chip seal
- Crack seal
- Thin HMA overlay

4.9.1 Pre-Treatment Repair

(a) Crack Seal:

Crack seal application according to 8 out of 11 districts is reported to be one of the most effective pre-treatments. While most districts report it to be frequently used, district 8 reports "next most frequently used" and district 9 uses crack seal "sometimes". In conclusion, it is inferred that the survey responses indicate crack seal application proves to be a frequent treatment for medium severity distresses over a large range of traffic classification.

4.9.2 Preventive Maintenance Treatment

(a) Chip Seal:

Chip seals are used by three districts to address primarily low to medium severity cracking and weathering, which most other districts typically address using overlays or crack seal—predominantly to address low severity cracking. On average, these districts get 3 to 5 years service life from their chip seals, with traffic volumes up to 30,000 ADT in District 8—although District 8 does consider chip seals only "somewhat" effective. On the other hand, Districts 4 and 12 all report chip seals being the "next most" effective treatment they use, while District 10 considers chip seals one of its more effective and frequently used treatments. Three Districts also report sometimes using sand seals to address bleeding of low to medium severity, which is typically not addressed by other districts, preferring to address high-severity bleeding with overlays or microsurfacing. Two of the three districts reportedly using sands seals, note only finding them "somewhat" effective, while the other district considers it one of the "least" effective treatments it typically uses.

(b) Thin HMA Overlay:

A thin HMA overlay is used by most of the districts to address most forms of medium severity distresses. The overlay method is also effective by more than three districts to address the high severity distress. However, thin HMA overlays are used to address most of the distresses by most districts. The following figure represents the HMA overlay use reported by the Penn DOT districts. 5 out of 11 districts indicated the use of thin HMA overlay against medium severity patching whereas, 4 districts reported its use in case of fatigue cracking. Thin HMA overlay is also popular in the presence of medium severity pavement distresses such as weathering, longitudinal/transverse cracking, corrugations, and stripping. It appears that thin HMA overlay is consistently used amongst most districts for different medium and high severity distresses. However, only one district reports using thin HMA overlay for low severity distress conditions.

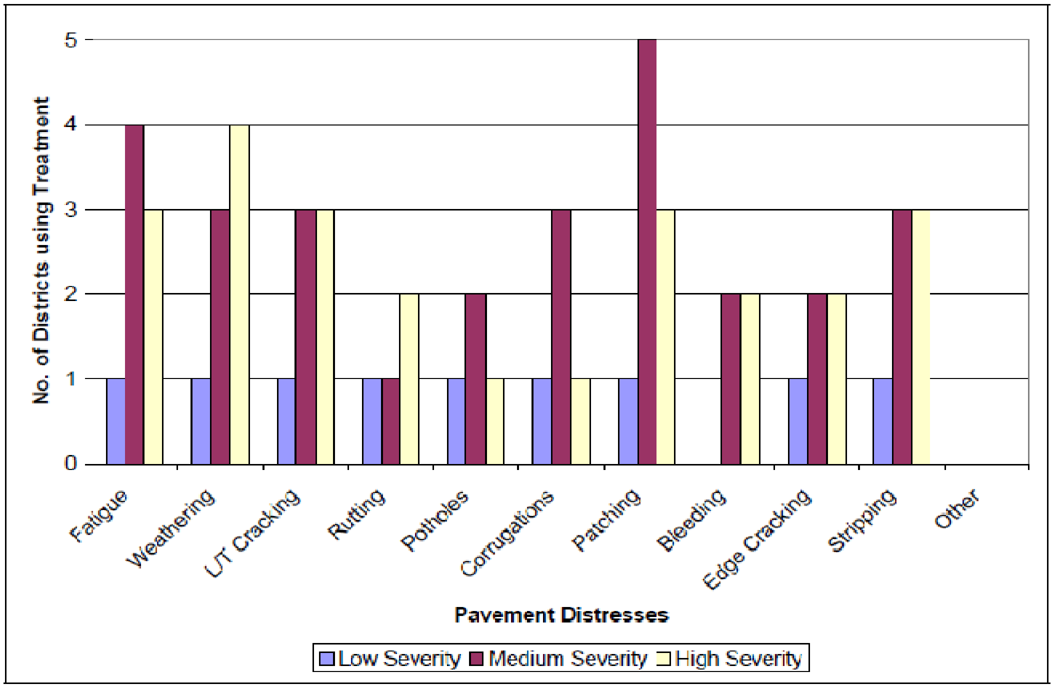

Figure 20. Number of PennDOT districts using thin HMA overlays to address various pavement distresses of low, medium, and high severity.

(c) Microsurfacing:

Microsurfacing is also used by a number of districts (5 of 11) to address primarily medium severity pavement distresses: fatigue cracking, longitudinal and transverse cracking, rutting, bleeding, and weathering and raveling. However, microsurfacing does not appear to be used extensively by the districts, nor consistently among them; for example, District 3 uses microsurfacing to address all five of the distresses previously listed, but Districts 10 and 11 only use it to address medium-severity bleeding. Districts 1 and 3 also note using microsurfacing to address stripping, which can be accelerated in susceptible pavements, negatively affecting crack and rut resistance. In general, microsurfacing, although typically only used “sometimes,” is considered “somewhat” effective by most districts using it. On the other hand, although it is reported to be frequently used in District 12, the district considers microsurfacing ineffective. Figure 18 represents the use of microsurfacing amongst the districts.

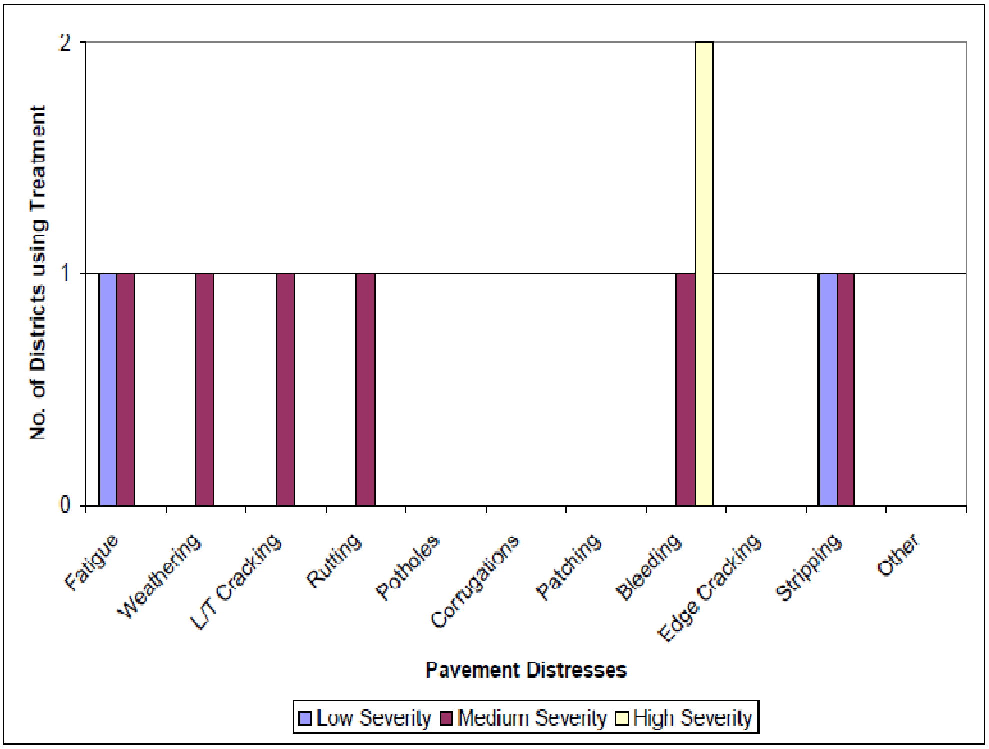

Figure 21. Number of PennDOT districts using microsurfacing to address various pavement distresses of low, medium, and high severity.

According to Penn DOT's Pavement Policy Manual, Publication 242, chip seals, slurry seals, and other surface treatments cannot be used on Interstate roadways; however, they may be used on other roadways. A summary of the survey responses from the Penn DOT districts effectiveness and frequency rating are represented in the table below.

Table 39. Pennsylvania District Survey – Frequency and Efficiency Rating for Preventive Maintenance Treatments

FREQUENCY AND EFFECTIVENESS RATING																						
Treatments / Classification	**PennDOT District Effectiveness / Frequency**																					
	1-0		**2-0**		**3-0**		**4-0**		**5-0**		**6-0**		**8-0**		**9-0**		**10-0**		**11-0**		**12-0**	
Crack Seal	3	-	-	-	1	1	1	1	1	1	1	1	2	2	1	3	1	1	1	1	1	1
Fog Seal	5	-	-	-	5	-	-	-	5	-	5	-	5	-	-	-	5	-	-	-	4	3
Sand Seal	5	-	-	-	4	1	-	-	5	-	5	-	5	-	5	5	3	3	-	-	3	3
Chip Seal	5	-	-	-	5	-	2	1	5	-	5	-	3	2	2	4	1	1	-	-	2	2
Double Chip Seal	5	-	-	-	5	-	3	1	5	-	5	-	5	-	-	-	3	1	-	-	2	2
Slurry Seal	5	-	-	-	5	-	-	-	5	-	5	-	5	-	-	-	5	-	-	-	4	3
Microsurfacing	2	-	-	-	2	1	3	2	5	-	5	-	3	3	-	-	3	1	-		4	2
Open Graded Friction Course	2	-	-	-	5	-	-	-	5	-	5	-	5	-	-	-	3	-	4	2	3	3
Rubberized Asphalt Chip Seal	5	-	-	-	5	-	-	-	5	-	3	2	4	3	-	-	0	1	-	-	4	3
Cape Seal	5	-	-	-	5	-	-	-	5	-	5	-	5		-	-	5	-	-	-	4	3
Polymer Modified HMA Overlay	1	-	-	-	1	1	-	-	2	3	5	--	3	3	4	2	3	2	1	1	3	1
HMA Overlay (< 2 ")	-	-	-	-	1	1	1	2	3	3	1	1	2	1	2	3	1	1	4	3	1	2
HMA Overlay (> 2 ")	-	-	1	1	4	1	3	2	3	1	5		1	1	3	1	1	1	4	2	2	2

Frequency rating:
1 – most frequently used, 2 – next most frequently used, 3 – sometimes used, 4 – rarely used, and 5 – never used
Effectiveness rating:
1 – most effective, 2 – second most effective, 3 – somewhat effective, 4 – least effective, 5 – not effective.

4.10 TREATMENT USE

The survey results were studied to find that at least half of Penn DOT's districts use crack seal, thin HMA overlays (<2 in), milling and overlay, polymer-modified asphalt overlays, and patch or base repair. While the most common treatments for high ADT roadways are thin HMA overlays, microsurfacing, and polymer modified HMA overlay are also relevant. All pavement distresses and severities are addressed, with HMA overlays used for all, including high-severity alligator cracking. Microsurfacing and polymer modified HMA also are seen to be widely used for a majority of medium to high severity distresses. Crack sealing is an effective pre-treatment repair method and is implemented for low to medium severity alligator cracking, transverse/longitudinal cracking, and edge cracking. Although some other forms of pre-overlay repairs such as leveling course, partial depth repair, and full depth repair are effective means of treating most distresses, the ability of these pre-treatments to provide service life extension is not discussed by the districts. While milling and overlay can be applied as a preventive maintenance treatment in most cases, some districts also use this method as a pre-overlay repair for microsurfacing. In general, thin HMA overlays are used extensively by Penn DOT districts, with the majority of districts reporting their performance to be one of the more effective treatments. The treatment use is also greatly influence by the frequency and effectiveness. While treatments such as microsurfacing are effective their frequency are much lesser. Whereas, preventive maintenance treatments such as thin HMA overlays, crack seal, and polymer modified HMA overlays are more effective on interstate pavements.

From the survey responses it can be seen that the treatment service life extension is closely linked to the traffic classification and the range of traffic levels. Although traffic amongst various other conditions, influences the type of distress observed on a pavement, the type of treatment applied depends on the severity and type of distress observed. However, pre-overlay repair methods are closely related to the type of distress and are also influenced by the sequence of treatment used. The thickness of a treatment is also a function of the type of distress however; the district survey does not highlight this finding. Another key factor in identifying the treatment type is the effectiveness of a treatment. Depending on the district practices and experience the most effective treatment might not always be the most frequently used one. The factors influencing frequency of treatment are not covered in this study.

Thus, the treatments most extensively used in Penn DOT districts can be listed as:

- Pre-Treatment Repair
    - Crack seal
    - Milling and overlay
- Preventive Maintenance Treatment
    - Thin HMA Overlay (<2 in)
    - Thin HMA Overlay (>2 in)
    - Microsurfacing
    - Polymer modified asphalt overlay

According to Penn DOT's current pavement preservation guidelines contained in the Pavement Policy Manual, Publication 242, the available treatment strategies for HMA-surfaced roadways include crack seal, patching, base repair, microsurfacing, thin HMA overlay, and mill and overlay (*PUB 242, 2007*). HMA overlays greater than 2 in thick and polymer-modified asphalt overlays appear to be typically reserved for high-severity diseases. Penn DOT's Pavement Preservation Guidelines for Federal Aid Projects, as appended to the Pavement Policy

Manual, Publication 242, states that overlay projects exceeding 1.5 in will not be considered pavement preservation except for the following:

- 1.5-in Superpave 9.5 mm, or 2-in Superpave 12.5 mm, mix with maximum 1-in scratch course.
- 1.5-in or 2-in milling and overlay depths may be exceeded to remove and replace existing pavement to correct rutting or other material problems.
- Microsurfacing or paver-laid seal/leveling course may be used to improve skid resistance, ride quality, and/or rutting, however, such treatments should occur before advanced distresses emerge.

5.0 PREVENTIVE MAINTENANCE - BEST PRACTICES

5.1 INTRODUCTION

The literature review, national level survey, and the district survey (Penn DOT) highlighted the best practices for preventive maintenance of bituminous surfaces. The state survey concentrated on the best practices and the current practices implemented by the State Agencies and the district survey provided in depth view of the various factors influencing the preventive maintenance practices. One of the objectives of this study is identifying the best practices. The availability and use of a treatment in Pennsylvania contributes to list of best practices. The results obtained from the literature review, state survey and district survey are compared in this section to enumerate the list of best practices. The identified best practices can be used as a lead-in for preventive maintenance strategies. The selection of a preventive maintenance strategy is influenced by conditions such as the current pavement condition, application temperature, treatment thickness, and pavement serviceability. The identified practices can be incorporated to form a set of guidelines and procedures to meet the needs of the given climatic conditions, available resources, materials, and other criteria. The objective of this section is to summarize the key best practices for preventive maintenance that can be used in Pennsylvania.

5.2 KEYS TO BEST PRACTICES

The previous chapters highlight the presence of number of agencies with extensive experience in preventive maintenance with a fairly well defined preventive maintenance technique. Some of the important elements for the implementation of best practices in flexible pavement preservation are:

- Pre-Treatment Repair
    - Crack seal
    - Milling and overlay
- Preventive Maintenance Treatment
    - Thin HMA Overlay (<2 in)
    - Thin HMA Overlay (>2 in)
    - Microsurfacing
    - Polymer modified asphalt overlay
- Available Treatments
- Treatment Sequencing
- Effectiveness of Treatments

These are discussed further in the remainder of this section.

Available Treatments: A preventive maintenance treatment is an integral part of pavement preservation. The key to pavement preservation are a broad range of available treatments. The previous chapters enumerate the various factors and conditions that contribute to identifying effective and best preventive maintenance practices. This section enumerates the best practices concluded from the literature review, state survey, and district survey. In summary, a list of treatments available for implementation on interstate pavements in Pennsylvania is identified in this section.

Treatment Sequencing: Treatments are more cost-effective when applied in the early stages of pavement distress, before a failure occurs in the life of a pavement. The performance of a preventive maintenance treatment is directly related to the condition of pavements. Early application is intended to yield benefits that exceed the cost of a large scale single treatment. Furthermore, by extending the life of a pavement section, preventive maintenance accommodates a distribution of costs. For example, MnDOT reports that its preventive maintenance program enables them to optimize the network condition with a given preservation budget, resulting in more stable funding needs *(Dai et al., 2008).*

Effectiveness of Treatments: A systematic approach to preventive maintenance over time is to improve pavement surface quality, extend service life, and delay pavement failures, reducing the need for more extensive maintenance and delaying the need for rehabilitation and reconstruction. The goal of a preventive maintenance is to cost-effectively and efficiently extend pavement life. The previous chapters explained in detail the extension in service life, conditions under which the treatments are most effective in increasing performance.

5.3 BEST PRACTICES FINDINGS

This section highlights the best practice findings for the literature review, state survey, and Penn DOT district survey. The literature review report indicated an extensive list of treatments used for preventive maintenance by different state agencies. Further, not all the treatments were distributed evenly in all states. While almost all states reported in chapter 2 indicated the use of treatments such as thin HMA overlay, microsurfacing, and crack seal, some states reported using other treatments as well. The state survey however, narrowed the treatment use for pavements in surrounding states and those with similar conditions. The Penn DOT district survey provided a list of treatments particular to the districts of Pennsylvania. These findings are summarized in the following sub-section.

5.3.1 Best Practices – Literature Review

The literature review in Chapter 2 summarizes the preventive maintenance treatments for 11 states. Analyzing and comparing these treatments a list of common practices is as follows:

- Crack filling and crack seal
- Chip Seal
- Cape Seal
- Slurry Seal
- Thin HMA overlay
    - Open Grade Friction Courses
    - Thin Bonded Wearing Course (Novachip)
- Single course microsurfacing
- Cold milling and overlay

5.3.2 Best Practices – State Survey

Chapter 3 highlights the findings from the state survey. The treatments that are used in these states are for Pennsylvania interstate and interstate look-alike pavements. A list of the most effective preventive maintenance treatment based on the current practice is as follows:

- Crack filling and crack seal
- Chip Seal
- Thin HMA overlay
    - Dense Graded Overlays
    - Open Grade Friction Courses
    - Stone Matrix Asphalt
        - Thin Bonded Wearing Course (Novachip)
- Single course microsurfacing
- Cold milling and overlay.

5.3.3 Best Practices – District Survey

The Penn DOT district survey as explained in Chapter 4 was elaborate and highlighted the various conditions of treatment use. The survey results indicated the extensive use of the following treatments:

- Crack filling and crack seal
- Thin HMA overlay
    - Dense Graded Overlays

  - Open Grade Friction Courses

- Thin Bonded Wearing Course (Novachip)
- Polymer modified overlay
- Single course microsurfacing
- Cold milling and overlay

In summary, the survey results and the literature review suggests that one of the effective preventive maintenance treatments is crack sealing the pavement at early stages. However, crack seal application is most beneficial in case of low severity distresses and initial stages of cracking. While chip sealing has proved to be effective in low traffic conditions, cape sealing has shown considerable increase in service life on high traffic pavements. Thin HMA overlays (less than 2 inches) and polymer-modified HMA overlays are very effective and increase the service life by a minimum of 8 years. These methods not only improve the riding quality of the pavement by reducing the amount of distress, but also improve the life of the pavement. For many interstate and high volume primary routes, an HMA overlay of stone matrix asphalt is the most effective method of preservation, lasting 12 to 15 years in most instances. Although the cost of stone matrix asphalt mix is approximately 25 to 35 percent greater than dense graded mixes, its life is much longer.

Thin bonded wearing course is effective in improving the ride quality of the pavement and increases the service life by about 8 years. Single course microsurfacing improves the service life by about 8 to 10 years and increases the resistance of pavements to deterioration. This method is most effective on pavements with medium to high severity distresses. While milling and overlay also proves to be a highly effective method for maintenance and retards the early onset of distress, polymer-modified HMA is most effective on pavements exhibiting high severity distress.

The primary requirement of an effective preventive maintenance treatment includes an understanding of the availability of treatments, conditions of effective application, and their performance based on the different factors as explained in the preceding sections. However, the effectiveness of a preventive maintenance treatment is also a result of the sequence of application and time of application.

Best practices related to pavement preservation are an integration of objectives, treatment strategies, policies, and guidelines and include a means of tracking and measuring progress and performance. While specific treatment strategies vary widely among state highway agencies depending upon many state-specific factors including economic climate, contracting environment, materials availability, public expectations, treatment performance expectations, safety considerations and so on, the definition of best practices is fairly well established. The summary of preventive maintenance practices can be represented as shown in the figure below.

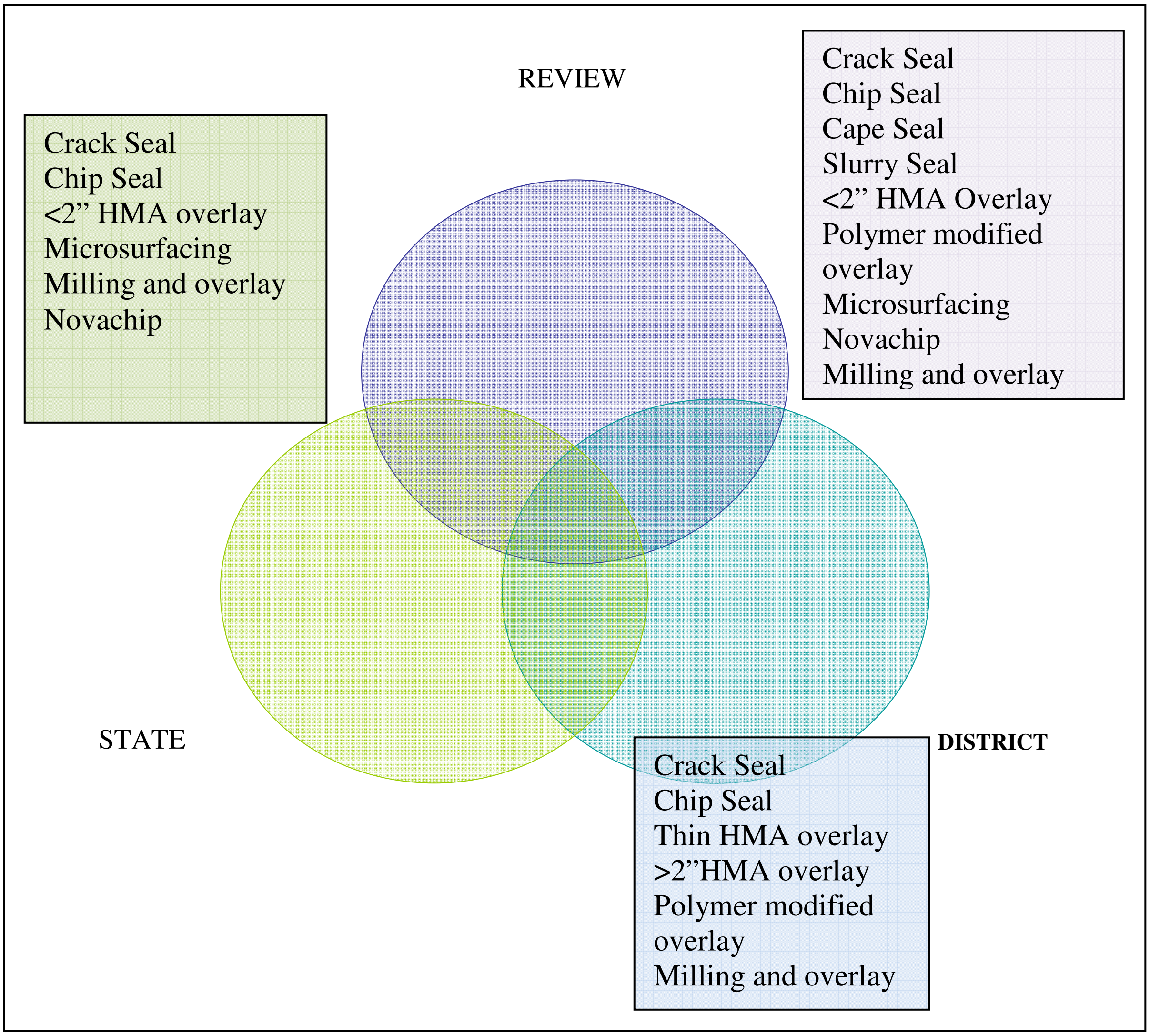

Figure 22. Summary of Preventive Maintenance Treatments

6.0 SUMMARY, CONCLUSIONS & RECOMMENDATIONS

6.1 EXECUTIVE SUMMARY

This study has highlighted the various preventive maintenance practices and their relationship with the various factors. While the state survey indicated a rage of current and best practices, the district survey validated the Penn DOT publication 242 guidelines in terms of conditions of application, and practices. The previous chapter highlights the best practices findings of each of these stages of the study. The identification of the best practices and effective preventive maintenance treatments is one of the main aims of this study. Furthermore, the list of treatments determined can be used to form guidelines for preventive maintenance treatment on interstate roadways. The list of best practice treatments derived from the best practices are:

- Crack filling and crack seal
- Chip Sealing
- Thin HMA overlay
    - Dense Graded Overlays
    - Open Grade Friction Courses
- Thin Bonded Wearing Course (Novachip)
- Polymer modified overlay
- Single course microsurfacing

- Cold milling and overlay

The various aspects of the study have highlighted the conditions influencing preventive maintenance techniques, strategies of practices by state agencies, in-depth details of preventive maintenance implementation within Pennsylvania, and a list of available treatments. The application of a preventive maintenance treatment is not only influenced by these conditions, it is affected by the sequencing of the treatment, location application, and the guidelines followed in the implementation. However, these treatments are best applied when in line with a strategy or guidelines for preventive maintenance.

A treatment is not independent of various other key aspects such as dedicated funding, program sequencing, and integration of the identified available treatments with the pavement decision making tools to streamline and build the knowledge base and to enhance data accessibility, accuracy, and analysis. This study concludes on the first stage of identifying the best practices. However, the results presented here can be used for the development of guidelines for a state agency in consideration with the local and regional conditions for the implementation of these preventive maintenance practices.

6.2 CONCLUSIONS

- Thin HMA overlay is most effective on almost all types of pavement distresses and extends the service life by about 5 to 10 years.

- Thick HMA overlays are reported to be an effective treatment against all pavement distresses over all ranges of traffic by extending the service life up to 10 years. This treatment is frequently used amongst Penn DOT districts.
- Crack sealing is used as an effective pre-treatment repair and extends the service life by 3 to 5 years. It is most advantageous when applied in the early stages of pavement life and at low to medium severity distresses. The use of crack sealing in stages of high severity cracking would not be a beneficial.
- Milling is an effective means of pre-treatment repair. However, milling is most effective when used in combination with thin HMA overlay. Milling to a depth of 2 inches and overlay of about 2 to 3 inches is most effective in addressing almost all types of medium to high severity distresses.
- Polymer modified HMA overlay extends service life by about 5 to 8 years and effectively addresses high severity distresses.
- Although the frequency of microsurfacing is restrictive in most Penn DOT districts, the practice is effective methods against almost all types of high severity distresses. The service life extension provided by microsurfacing is about 5 to 8 years.
- Application of a leveling course is not extensive amongst the states, but majority of Pennsylvania districts implement this technique for pre-overlay repair. The leveling course used is about 1 inch thick and addresses all types of medium to high severity distresses.
- Although many states and districts report the use of chip sealing, its effect on high traffic pavements is observed to be varied. In general, it service life extension is about 3 to 5 years. It is most effective on pavements exhibiting low severity distresses.

- A number of state agencies report the use of Ultra thin bonded wearing courses or Novachip as a preventive maintenance treatment however; its efficiency is not validated. However, this treatment is not extensively used in Penn DOT districts.
- The surveys and the literature review conclude that treatments such as fog seal, sand seal, cape seal, and slurry seal report an average service life extension of 2 to 6 years. These treatments are used to address low severity distresses in some cases however, exhibit a low efficiency.

Thus, it can be concluded that the effective means of preventive maintenance is to crack seal the pavement at an early stage, this allows the pavement to recover from cracks on the pavement. Milling and overlay and thin HMA overlays are also effective means of preventive maintenance. Some other treatments that are not the most effective but are implemented in some states and districts are fog seal, flexible slurry, smooth seal, and ultra thin wearing course (Novachip). The effect of rejuvenators like that of fog seals also restores the pavement surface by improving the smoothness of the pavement. The flexible slurry system is also another effect means of rehabilitation and it avoids the rutting of the pavement to large. Smooth seal is also an effective method of preventing the deterioration of the pavement and extends the life of the pavement. It increases the flexibility of the pavement and a layer of surfacing of about 1" improves its surface properties.

6.3 RECOMMENDATIONS

On a micro level this study highlights the use of treatments such as crack seal, HMA overlays, microsurfacing, chip seal, and polymer modified HMA overlays which contribute to a considerable increase in service life. However, these treatments must be applied in conjunction with the conditions of application.

- Early stages of pavement distress – crack seal.
- Pre-Treatment repair for medium to high severity distresses – milling and overlay.
- Pre-Treatment repair for high severity distresses – leveling course.
- For all major high severity distresses and traffic conditions – thin HMA overlays.
- High severity distresses – polymer modified HMA overlay.
- High severity distresses and as a pre-treatment repair in some cases – microsurfacing.
- Low to medium severity distresses – chip seal.

However, the implementation or application of a preventive maintenance treatment is not only a function of various conditions and factors that directly control the treatment effectiveness but also involves a strategic approach. This study recommends the development of comprehensive guidelines for preventive maintenance of bituminous surfaced pavements. A holistic approach of preventive maintenance includes sequencing of treatments, pavement age, cost of maintenance, and dedicated funding. The development of guidelines based on these findings shall channelize the applicability and performance of the interstate pavements.

The effectiveness of a preventive maintenance treatment is closely linked to a program for maintenance and treatment. This study recommends the development of a program to encourage monitoring and application of preventive maintenance treatments to provide considerable benefits. The integration of preventive maintenance in to pavement management system would further facilitate the presence of data with respect to applicability and efficiency of a preventive maintenance treatment.

APPENDIX A

NATION WIDE SURVEY QUESTIONNAIRE

The survey questionnaire sent to the various state agencies consisted of nine questions. The questionnaire was sent to nine states. The responses were received from five states namely, New York, Ohio, Michigan, Minnesota, and Virginia. A blank copy of the questionnaire as attached below.

A.1 NATION WIDE SURVEY QUESTIONNAIRE

A blank copy of the survey questionnaire distributed to the different states is attached in this section.

1. How does your agency differentiate between pavement preservation and pavement maintenance?
2. What techniques are you using for preservation?
3. When is a Hot-Mix Asphalt (HMA) overlay used as a preservation technique and what are the current practices and best practices for its use?
4. Are there any innovations or specific technologies used in the preservation and maintenance of bituminous overlays?
5. What are your pavement preservation guidelines used for deciding the preservation methodologies?
6. Explain the Bituminous Overlays and Techniques used for pavement preservation.
7. Based on current practices, what are your most effective methods of pavement preservation and what are the following characteristics of that method:
    a. Life cycle time.
    b. Cost of construction.
    c. Thickness of overlay used.
    d. Mix design or components.
8. Please mention any sources or articles that need to be referred for the pavement preservation summary.
9. Please mention if there are any other preservation related details.

A.2 NATION WIDE SURVEY RESPONSES

Virginia Department of Transportation

Contact Person:

Trenton M. Clark, P.E.
Asphalt Pavement Field Engineer
Culpeper, Staunton, and NOVA (Northern Virginia) Districts
PO Box 308
551 Mechanic Street
Luray, VA 22835
(540) 860-2495
(540) 743-7249 (fax)

1. Differentiation between Pavement preservation and Pavement Maintenance.

In general, VDOT does not differentiate between pavement preservation and pavement maintenance. In general, thin AC overlays and surface treatments are used for pavement preservation – when the pavement is in good condition. When the pavement has structural deficiency or extensive structural failures, then a thicker AC overlay, patching, milling, etc. is used to improve the pavement.

2. What are the techniques that are being used for preservation?

Primarily thin AC overlays (<2"), surface treatments, microsurfacing, and slurry seals for asphalt surfaced roads.

3. Innovations or technology in the preservation and maintenance of bituminous overlay.

Recent innovations or technology would be the use of thin hot mix asphalt overlays similar to the NOVACHIP™ product. We tried using a macro-texture surface treatment, but it was not very successful.

4. What is the pavement preservation guidelines used for deciding the preservation methodologies?

No formal guidelines have been established. The decision is left to the districts and may use past experience in determining the pavement preservation strategies.

5. The current practice of maintenance and the Best Practice of Preservation and Maintenance – Comparison.

Again, we do not have set guidelines or requirements. We require pavements in poor condition to have an engineering evaluation; these pavements have severe cracking, structural failures, etc. These pavements need either restorative maintenance or reconstruction. For pavements that do not fall into this category, the district pavement manager determines what type of maintenance/preservation is performed.

6. Bituminous Overlays and Techniques used for the same.

Most of VDOT's projects consist of either a straight overlay or a mill and replace. The typical thicknesses are 1.5 to 2 inches. In some instances, the thickness is increased to address structural failures. In 2008, we placed 68 lane miles of thin hot mix asphalt overlay (similar to NOVACHIP™) on I-95. VDOT uses dense graded asphalt for the majority of overlays designed using the SUPERPAVE™ system. On selected routes, VDOT will use stone matrix asphalt.

7. Most Effective method of preservation: (Current Practice)

This answer depends on the situation. For many interstate and high volume primary routes, SMA is the most effective method of preservation. The life cycle time exceeds 12 to 15 years in most instances. The cost is approximately 25 – 35% than dense graded mixes, but the life is much longer. Most SMA overlays are 1.5" to 2" using either PG 70-22 or PG 76-22 for the binder.

For lower volume primary roads, we will use a thin AC overlay. On many secondary roads, we will use either a thin AC overlay, slurry seal, or chip seal. The life of each varies depending on the many factors.

   i. Life cycle time

 b. Cost of construction
 c. Thickness of overlay used
 d. Mix design or components

8. Sources or articles that need to be referred for the pavement preservation summary.

None at this time.

9. Any other preservation related details.

Michigan Department of Transportation (MDOT)

Contact Person:

Brandy Donn, P.E.
Pavement Management Engineer
North Region Office
Michigan Department of Transportation
1088 M-32 East
Gaylord, MI 49735
(989) 731-5090
donnb@michigan.gov

1. Differentiation between Pavement preservation and Pavement Maintenance.

   Pavement Preservation is a program that employs a network level, long term strategy that enhances the pavement performance by using cost effective practices that extend the life of the pavement, improve safety and meet motorist expectations.

   Pavement Maintenance is work that is performed on a routine basis to maintain and preserve the condition of the highway system or to respond to specific conditions and events that restore the highway system to an adequate level of service.

2. What are the techniques that are being used for preservation?

   Flexible and Composite Pavement Treatments:
   Crack Treatments, Overband Crack Filling, HMA (Hot Mix Asphalt) Shoulder Ribbons, Chip Seals, Single Course Microsurfacing, Double Course Microsurfacing, Cold Milling with Non-Structural Bituminous Overlay, Ultra-Thin HMA Overlay, HMA Overlay, Ultra-Thin Whitetopping and Fiber Mat with Single Course Micro-Surface.

   Rigid Pavement Treatments:
   Concrete Joint Resealing, Diamond Grinding, Concrete Spall Repair, Concrete Crack Sealing, Full Depth Joint Repairs, Full Depth and Partial Depth Concrete Pavement Repairs, Reinforced Concrete Pavement Repair, Dowel Bar Retrofit

HMA Shoulder Ribbons and Open Graded Underdrain Outlet Cleaning and Repair.

3. When is overlay used as a preservation technique and what are the current practices and Best Practice for the same?

   HMA overlays are used on pavements with a good base condition and a uniform cross section. It is placed on pavements with a minimum remaining service life (RSL) of 3 years. The visible surface distress may include moderate raveling, longitudinal and transverse cracks and small amounts of block cracking. This treatment performs best on flexible pavement structures but it can also be placed on composite pavements depending on the extent of the reflective cracking.

4. Innovations or technology in the preservation and maintenance of bituminous overlay.

   HMA Ultra Thin Overlays are used on pavements with low severity cracking, raveling/weathering, friction loss, roughness, low severity bleeding.

   Crack Sealing, Chip Sealing, Microsurfacing, maintaining positive drainage are other ways to preserve bituminous overlays.

5. What is the pavement preservation guidelines used for deciding the preservation methodologies?

   Pavement Preservation can be performed on any highway. The projects should be relatively simple and focus on pavement structures with more than 2 years of remaining service life. Severely distressed pavement structures or pavement with a severely distorted cross section are generally not project candidates. Project work should be kept between the outside edges of the shoulders or curbs. Minor safety work can be included but should not be extensive.

6. Bituminous Overlays and Techniques used for the same.

   ? I think this has already been answered in #3.

7. Most Effective method of preservation: (Current Practice)

a. Life cycle time
b. Cost of construction
c. Thickness of overlay used
d. Mix design or components

MDOT does not have one method of preservation that is better than others. Although the HMA overlay is considered as a high level surface treatment it may not be the most effective method of preserving all pavements. Each pavement location is looked at individually for the defects that need to be corrected and the options are then evaluated to find the most effective method for that pavement section. We also like to use a mix of fixes on our pavements to keep competition within the industry.

8. Sources or articles that need to be referred for the pavement preservation summary.

MDOT is in the process of developing a Capital Preventive Maintenance Manual. When it is complete it will be posted on our website.

9. Any other preservation related details.

Special Provisions for our preservation techniques are attached.

New York Department of Transportation (NYSDOT)

Contact Person:

Zoeb Zavery, PE
NYS DOT
Materials Bureau - POD 34
50 Wolf Road
Albany, NY 12232
(518) 485-5277
zzavery@dot.state.ny.us

1. Differentiation between Pavement preservation and Pavement Maintenance.

Pavement Preservation is the overall strategy, of which preventive maintenance is a component. According to a September 2005 memorandum from FHWA, "A

Pavement Preservation program consists primarily of three components: preventive maintenance, minor rehabilitation (non-structural), and some routine [maintenance] activities…" Our application of these concepts is to say that preventive maintenance includes thin overlays such as chip seal, slurry seal, microsurfacing, paver-placed surface treatment, etc., and 1-1/2 inch HMA overlays; pavement preservation includes mill and fill and cold-in-place recycling in addition to the preventive maintenance treatments.

2. What are the techniques that are being used for preservation?

    a. **Crack sealing**
    b. **Mill & Fill**
    c. **Thin overlays**
    d. **Microsurfacing**
    e. **PPST (pavement preservation surface treatment)**
    f. **Heater Scarification w/overlay**
    g. **Cold-in-place recycling**

3. When is overlay used as a preservation technique and what are the current practices and Best Practice for the same?

Preservation treatments are applied to pavements before the distress becomes too severe. Generally, the ideal window of opportunity for preservation is when the distress is occasional in frequency and minor in severity (the 3rd or 4th year at a 7 on our 1-10 rating scale, which occurs about 10-12 years after the last treatment). Thin overlays perform best at the early stage of this window, and 1-1/2" HMA overlays can perform well late in the window.

4. Innovations or technology in the preservation and maintenance of bituminous overlay.

    a. **Rubber modified chip seal**
    b. **Surface Treatment with sand seal**

5. What is the pavement preservation guidelines used for deciding the preservation methodologies?

The Department's Comprehensive Pavement Design Manual contains a section on pavement preservation treatments. Guidance is provided on the conditions and limitations for the selection of specific treatments. This Manual is currently under update to better reflect current pavement preservation strategies and performance information.

6. Bituminous Overlays and Techniques used for the same.

The Comprehensive Pavement Design Manual also contains information on conditions for selection of rehabilitation and reconstruction techniques.

7. Most Effective method of preservation: (Current Practice)
    a. Life cycle time
    b. Cost of construction
    c. Thickness of overlay used
    d. Mix design or components

There are many tools in the toolbox for pavement preservation, each with characteristics that enhance or disincline its use at a specific location. The most effective use of any of the treatments is most influenced by the timing of the application; not too soon to shorten the useful life of the previous treatment, and not too late to allow the distress to reach a severity that will adversely impact the performance of the preservation treatment.

8. Sources or articles that need to be referred for the pavement preservation summary.

The National Center for Pavement Preservation website (http://www.pavementpreservation.org/) has a wealth of information and resources.

9. Any other preservation related details.

None

Ohio Department of Transportation (ODOT)

Contact Person:

Adam Au
Office of Pavement Engineering,
Ohio DOT
(614) 995-5992
Adam.au@dot.state.oh.us

The Ohio DOT refers to the two manuals below for the identification of the pavement distress rating and to assess the condition of the pavement. It then follows the information in the *Pavement Preventive Maintenance Program Guidelines* to analyze the effective preventive treatment that is applied for the particular identified conditions. However, the respondent stated that the cost effectiveness of the different preventive maintenance techniques are currently under study. So far, single layer chip seals have proven to be the most cost effective treatment. They cost roughly $13,000 per lane mile and last from 3 to 5 years.

The manuals that are used for reference are:

Pavement Condition Rating System – Ohio Department of Transportation, Office of Pavement Engineering

Pavement Preventive Maintenance Program Guidelines – 2001, Ohio Department of Transportation, Office of Pavement Engineering

1. How does your agency differentiate between pavement preservation and pavement maintenance?

   The ODOT Pavement Preventive Maintenance Guidelines states, "Preventive Maintenance (PM) is a planned strategy of cost effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, extends the service life, and maintains or improves the functional condition of the system without substantially increasing structural capacity."

"Pavement Preservation - The sum of all activities undertaken to provide and maintain serviceable roadways; this includes Reactive and Preventive Maintenance as well as Minor and Major Rehabilitation."

2. What techniques are you using for preservation?

The ODOT Pavement Preventive Maintenance Guidelines states the following methods of preservation and maintenance,

o Crack Sealing – Flexible, Composite and Rigid Pavements.
o Chip Seal
o Microsurfacing
o Polymer Modified Asphalt Concrete
o Thin Hot Mix Overlays

3. When is a hot-mix asphalt (HMA) overlay used as a preservation technique and what are the current practices and best practices for its use?

The Thin HMA Overlays section of the ODOT Pavement Preventive Maintenance Guidelines states the following:

"Pavement Condition Considerations: In order to assure HMA overlays are specified for the proper pavements and at the proper time, pavement condition must be evaluated. A GQL query of PCR distress codes is an excellent way to produce a preliminary list of HMA candidates. It is important to understand that PCR's are representative of the average condition found by the rater, and may not be indicative of an isolated pavement distress. The pavement review team as outlined in ODOT's Pavement Policy is to perform a field review of HMA candidates to insure a particular pavement section is acceptable. The conditions that need to be reviewed are also listed in the manual."

4. Are there any innovations or specific technologies used in the preservation and maintenance of bituminous overlays?

5. What are your pavement preservation guidelines used for deciding the preservation methodologies?

The ODOT Pavement Preventive Maintenance Guidelines are used for the preservation methodologies.

6. Explain the Bituminous Overlays and Techniques used for pavement preservation.

7. Based on current practices, what are your most effective methods of pavement preservation and what are the following characteristics of that method:
    a. Life cycle time
    b. Cost of construction
    c. Thickness of overlay used
    d. Mix design or components

The respondent stated in the response that the Single Layer Chip Seal has been the most effective treatment and provides a service life of 3 to 5 years. It is the most cost effective technique and is about $ 13,000 per lane mile.

8. Please mention any sources or articles that need to be referred for the pavement preservation summary.

9. Please mention if there are any other preservation related details.

Minnesota Department of Transportation (MnDOT)

Contact Person:

Roger Olson
Minnesota Department of Transportation
Office of Materials
1400 Gervais Ave.
Maplewood, MN 55109
(651) 366-5517
(651) 366-5461 fax
roger.olson@dot.state.mn.us

1. Differentiation between Pavement preservation and Pavement Maintenance.

Pavement Preservation is used as a proactive tool, crack seal, chip seal slurry seal etc, are the common treatments. Pavement maintenance is used as a reactive tool such as patching, spot overlay etc.

2. What are the techniques that are being used for preservation?

For HMA: Crack seal, fog seal, chip seal, microsurfacing, thin overlay. For PCC planing, retrofit dowels joint resealing are the most common

3. When is overlay used as a preservation technique and what are the current practices and Best Practice for the same?

A thin overlay less than 2 inches is considered as preservation, usually used when there is some significant surface distress, to help restore ride. Milling and overlaying is often used as a surface preparation method.

4. Innovations or technology in the preservation and maintenance of bituminous overlay.

We have experimented with using a variation of microsurfacing as a preoverlay treatment, called flexible slurry which is a microsurfacing product with a softer base binder and higher asphalt content.

5. What is the pavement preservation guidelines used for deciding the preservation methodologies?

Pavement Management has developed a decision tree to select treatments for given conditions, this is a network level tool for programming purposes. Most agencies use empirical experience to develop a program, often based on a fixed time schedule, such as a surface treatment at year 5.

6. Bituminous Overlays and Techniques used for the same.

See question 5

7. Most Effective method of preservation: (Current Practice)
    a. Life cycle time
    b. Cost of construction
    c. Thickness of overlay used
    d. Mix design or components

Although life cycle cost and mix design components are considered most effective, the cost of construction and thickness of overlay (ie thin overlays) are more commonly used

8. Sources or articles that need to be referred for the pavement preservation summary.

The national center for pavement preservation (NCPP) has links to many articles and reports related to pavement preservation.

9. Any other preservation related details.

There are many preservation partnerships being created such as the Midwest pavement preservation partnership, etc there is a northeast pavement preservation partnership as well (see NCPP for links) These are a good source of information exchange related to pavement preservation.

APPENDIX B

LONG TERM PAVEMENT PERFORMANCE DATA

The long term pavement performance database presents with information on the different preventive maintenance treatments. The summary of LTPP findings are tabulated in the following section.

Table 40. Long Term Pavement Performance – Chip Seal

CHIP SEAL – LONG TERM PAVEMENT PERFORMANCE								
SHRP ID	STATE CODE	SURFACE COND	CRACK TYPE	SURFACE PREP	ASPHALT GRADE	ACTUAL TEMP	PAVE TEMP	AIR TEMP
A350	IN	Normal	Longitudinal Cracking	Sweep and clean only	30	155	86	79
A350	MD	Normal	Transverse Cracking	None	35	150	99	88
C350	MI	Normal	Edge Cracking	Sweep and clean only	30	165	93	76
A350	MI	Normal	Transverse Cracking	Sweep and clean only	30	155	84	74
B350	MI	Normal	Transverse Cracking	Sweep and clean only	30	145	60	60
D350	MI	Normal	Transverse Cracking	Sweep and clean only	30	160	106	80
D350	MN	Normal	Alligator Cracking	Sweep and clean only	30	-	96	76
A350	MN	Normal	Block Cracking	Sweep and clean only	30	178	78	76
B350	MN	Normal	Transverse Cracking	Sweep and clean only	30	155	88	82
C350	MN	Normal	Transverse Cracking	Sweep and clean only	30	170	100	83
A350	NY	Normal	Transverse Cracking	None	35	160	98	92
B351	NY	Slightly Oxidized	Transverse Cracking	None	30	180	70	75
B352	NY	Slightly Oxidized	Transverse Cracking	None	30	180	100	75
B354	NY	Slightly Oxidized	Transverse Cracking	None	30	180	70	75
B350	NY	Normal	Longitudinal Cracking	None	35	150	90	87
A350	PA	Flushed (wheel path)	Longitudinal Cracking	None	35	150	75	75
B350	PA	Flushed (wheel path)	Longitudinal Cracking	None	35	150	80	85
A350	VI	Flushed (wheel path)	Longitudinal Cracking	None	35	162	86	85

Table 41. Long Term Pavement Performance – Crack Seal

CRACK SEAL - LONG TERM PAVEMENT PERFORMANCE								
SHRP ID	STATE CODE	PAVEMENT COND	SURFACE COND	CRACK SEVERITY	CRACK TYPE	RELATIVE HUMIDITY	PAVE TEMP	SEAL THICK
A330	IN	Clean	Normal	Low	Longitudinal Cracking	-	86	0.37
A330	MD	Clean	Normal	Low	Transverse Cracking	70	99	0.13
A331	MD	Mostly Clean	Normal	Low	Transverse Cracking	57	46	0.1
A330	MI	Clean	Normal	Low	Longitudinal Cracking	55	84	0.4
B330	MI	Clean	Normal	Low	Transverse Cracking	40	-	0.35
C330	MI	Clean	Badly Oxidized	Low	Longitudinal Cracking	40	93	0.37
D330	MI	Clean	Normal	Medium	Edge Cracking	45	106	0.5
A330	MN	Clean	Normal	Low	Block Cracking	83	78	0.4
B330	MN	Clean	Normal	Low	Transverse Cracking	1	86	0.4
C330	MN	Clean	Slightly Oxidized	Low	Transverse Cracking	32	100	0.35
D330	MN	Clean	Normal	Low	Alligator Cracking	32	96	0.3
A330	NY	Clean	Normal	Low	Transverse Cracking	62	98	0.1
A331	NY	Clean	Badly Oxidized	Medium	Alligator Cracking	57	105	0.13
B330	NY	Clean	Normal	Low	Transverse Cracking	50	90	0.1
B331	NY	Clean	Normal	Low	Transverse Cracking	50	75	0.13
A330	PA	Clean	Flushed in wheel	Low	Longitudinal Cracking	54	102	0.1
B330	PA	Clean	Flushed in wheel	Low	Longitudinal Cracking	30	80	0.1

Table 42. Long Term Pavement Performance – Slurry Seal

SLURRY SEAL - LONG TERM PAVEMENT PERFORMANCE						
SHRP ID	STATE CODE	CRACK TYPE	CRACK SEVERITY	ASPHALT GRADE	PAVE TEMP	AIR TEMP
A320	IN	Transverse Cracking	Low	34	86	79
A320	MD	Transverse Cracking	Low	34	99	88
A320	MI	Alligator Cracking	Low	34	62	62
A321	MI	Alligator Cracking	Low	34	62	62
B320	MI	Transverse Cracking	Low	34	67	69
B321	MI	Transverse Cracking	Low	34	69	70
C320	MI	Edge Cracking	Low	34	93	76
D320	MI	Transverse Cracking	Low	34	106	80
A320	MN	Block Cracking	Low	34	78	76
B320	MN	Transverse Cracking	Low	34	97	86
C320	MN	Transverse Cracking	Low	34	100	83
D320	MN	Alligator Cracking	Low	34	103	83
A320	NY	Transverse Cracking	Low	34	98	92
A321	NY	Alligator Cracking	Medium	35	115	81
B320	NY	Longitudinal Cracking	Low	34	90	87
A320	PA	Longitudinal Cracking	Low	34	102	90

Table 43. Long Term Pavement Performance – SPS 5 Overlay Layers

LAYER No.	DESCRIPTION		MATERIAL TYPE		MEAN THICKNESS (in.)	
	MN	NJ	MN	NJ	MN	NJ
SHRP ID - 0501						
1	subgrade		sandy clay	Clayey Sand		
2	subbase		gravel (uncrushed)	Soil-Aggregate Mixture (Predominantly Coarse-Grained Soil)	12.3	66
3	base layer		crushed stone, gravel or slag	gravel (uncrushed)	5.2	10
4	ac layer below surface		HMA, dense graded	HMA, dense graded	4.9	6
5	original surface layer		HMA, dense graded	HMA, dense graded	2	3.2

Table 43 (continued)

LAYER No.	DESCRIPTION		MATERIAL TYPE		MEAN THICKNESS (in.)	
	MN	NJ	MN	NJ	MN	NJ
SHRP ID – 0502						
1	Subgrade		sandy clay	Clayey Sand	-	-
2	Subbase		gravel (uncrushed)	Soil-Aggregate Mixture (Predominantly Coarse-Grained Soil)	12.4	41
3	base layer		crushed stone, gravel or slag	gravel (uncrushed)	5.1	10
4	ac layer below surface		HMA, dense graded	HMA, dense graded	4.9	6.2
5	original surface layer		HMA, dense graded	HMA, dense graded	2	2.6
6	Overlay		Recycled Asphalt Concrete Hot,	Recycled Asphalt Concrete Hot, Central Plant Mix	2	2

Table 43 (continued)

LAYER No.	DESCRIPTION		MATERIAL TYPE		MEAN THICKNESS (in.)	
	MN	NJ	MN	NJ	MN	NJ
SHRP ID – 0503						
1	subgrade	subgrade	sandy clay	Clayey Sand	-	-
2	subbase	subbase	gravel (uncrushed)	Soil-Aggregate Mixture (Predominantly Coarse-Grained Soil)	12.4	18
3	base layer	subbase	crushed stone, gravel or slag	Soil-Aggregate Mixture (Predominantly Coarse-Grained Soil)	5.1	4
4	ac layer below surface	base layer	HMA, dense graded	gravel (uncrushed)	5.3	10
5	original surface layer	ac layer below surface	HMA, dense graded	HMA, dense graded	1.1	6
6	ac layer below surface	original surface layer	Recycled Asphalt Concrete Hot, Central Plant Mix	HMA, dense graded	3	3
7	overlay	ac layer below surface	Recycled Asphalt Concrete Hot, Central Plant Mix	Recycled Asphalt Concrete Hot, Central Plant Mix	1.5	3
8	-	overlay	-	Recycled Asphalt Concrete Hot, Central Plant Mix	-	2

Table 43 (continued)

LAYER No.	DESCRIPTION		MATERIAL TYPE		MEAN THICKNESS (in.)	
	MN	NJ	MN	NJ	MN	NJ
SHRP ID – 0504						
1	subgrade	subgrade	sandy clay	Clayey Sand	-	-
2	subbase	subbase	gravel (uncrushed)	Soil-Aggregate Mixture (Predominantly Coarse-Grained Soil)	12.6	12.6
3	base layer	subbase	crushed stone, gravel or slag	Soil-Aggregate Mixture (Predominantly Coarse-Grained Soil)	5.2	5.2
4	ac layer below surface	base layer	HMA, dense graded	gravel (uncrushed)	5.1	5.1
5	original surface layer	ac layer below surface	HMA, dense graded	HMA, dense graded	1.5	1.5
6	ac layer below surface	original surface layer	HMA, dense graded	HMA, dense graded	3.1	3.1
7	overlay	ac layer below surface	HMA, dense graded	HMA, dense graded	1.5	1.5
8	-	overlay	-	HMA, dense graded	-	1.5

Table 43 (continued)

LAYER No.	DESCRIPTION		MATERIAL TYPE		MEAN THICKNESS (in.)	
	MN	NJ	MN	NJ	MN	NJ
SHRP ID – 0508						
1	subgrade	subgrade	sandy clay	Clayey Sand	-	-
2	subbase	subbase	gravel (uncrushed)	Soil-Aggregate Mixture (Predominantly Coarse-Grained Soil)	12.4	18
3	base layer	subbase	crushed stone, gravel or slag	Soil-Aggregate Mixture (Predominantly Coarse-Grained Soil)	5.1	4
4	ac layer below surface	base layer	HMA, dense graded	gravel (uncrushed)	4.9	10
5	original surface layer	ac layer below surface	HMA, dense graded	HMA, dense graded	0.1	6.1
6	ac layer below surface	original surface layer	Recycled Asphalt Concrete Hot, Central Plant Mix	HMA, dense graded	4.6	1
7	overlay	ac layer below surface	Recycled Asphalt Concrete Hot, Central Plant Mix	Recycled Asphalt Concrete Hot, Central Plant Mix	1.5	3
8	-	ac layer below	-	Recycled Asphalt Concrete Hot, Central Plant Mix	-	3
9	-	overlay	-	Recycled Asphalt Concrete Hot, Central Plant Mix	-	2

Table 43 (continued)

LAYER No.	DESCRIPTION		MATERIAL TYPE		MEAN THICKNESS (in.)	
	MN	NJ	MN	NJ	MN	NJ
SHRP ID – 0509						
1	subgrade	subgrade	sandy clay	Clayey Sand	-	-
2	subbase	subbase	gravel (uncrushed)	Soil-Aggregate Mixture (Predominantly Coarse-Grained Soil)	12.6	18
3	base layer	subbase	crushed stone, gravel or slag	Soil-Aggregate Mixture (Predominantly Coarse-Grained Soil)	4.7	4
4	ac layer below surface	base layer	HMA, dense graded	gravel (uncrushed)	4.9	10
5	original surface layer	ac layer below surface	HMA, dense graded	HMA, dense graded	0.1	6.3
6	ac layer below surface	original surface layer	Recycled Asphalt Concrete Hot, Central Plant Mix	HMA, dense graded	1.8	1.2
7	overlay	ac layer below surface	Recycled Asphalt Concrete Hot, Central Plant Mix	Recycled Asphalt Concrete Hot, Central Plant Mix	1.5	2.5
8	-	overlay	-	Recycled Asphalt Concrete Hot, Central Plant Mix	-	2

Table 44. Long Term Pavement Performance – SPS 5 Overlay Placement Thickness

SHRP ID	MATERIAL TYPE	FIRST LIFT		SECOND LIFT		THIRD LIFT		TACK COAT?
		MD	NJ	MD	NJ	MD	NJ	
502	Recycled hot mix asphalt, central plant mix	2.4	2.4	-	-	-	-	Y
503	Recycled hot mix asphalt, central plant mix	2	3.5	2	-	-	-	Y
504	Hot mix, hot laid asphalt concrete, dense graded	2	4	2	-	-	-	Y
505	Hot mix, hot laid asphalt concrete, dense graded	2.5	2.5	-	-	-	-	Y
506	Hot mix, hot laid asphalt concrete, dense graded	2	3	-	-	-	-	Y
507	Hot mix, hot laid asphalt concrete, dense graded	2	3	1.9	-	2.1	-	Y
508	Recycled hot mix asphalt, central plant mix	2	3	1.8	-	2	-	Y
509	Recycled hot mix asphalt, central plant mix	2	3	-	-	-	-	Y
559	Hot mix, hot laid asphalt concrete, dense graded	2	2.5	-	-	-	-	Y
560	Hot mix, hot laid asphalt concrete, dense graded	2	1.5	-	-	-	-	Y
561	Hot mix, hot laid asphalt concrete, dense graded	1.9	-	-	-	-	-	Y
562	Hot mix, hot laid asphalt concrete, dense graded	2	-	-	-	-	-	Y
563	Hot mix, hot laid asphalt concrete, dense graded	2	-	-	-	-	-	Y

APPENDIX C

PENNSYLVANIA DISTRICT SURVEY SUMMARY

The survey questionnaire sent to the 12 districts in Pennsylvania included a number of questions to provide an insight on the preventive maintenance practices in Pennsylvania. A summary of the district responses are listed in the tables shown below.

The responses of each district to the survey questionnaire are available with the author for further reference. The response to the questionnaire is also present at the University of Pittsburgh, Department of Civil & Environmental Engineering.

Table 45. Penn DOT Survey – Pavement Distress Addressed by Preventive Maintenance Treatments (Districts 1, 2, and 3)

Treatment	Distress Severity	PennDOT District		
		1-0	2-0	3-0
Crack Seal	Low	T/L cracking, edge cracking		Patching, longitudinal joint cracking
	Medium			Alligator cracking, edge cracking
	High			
Sand Seal	Low			Bleeding
	Medium			
	High			
Microsurfacing	Low	Alligator cracking, stripping		
	Medium			Alligator cracking, weathering/raveling, stripping, T/L cracking, longitudinal joint cracking
	High			
Polymer-modified HMA Overlay (2 in)	Low			
	Medium	Alligator cracking, weathering/raveling, stripping		
	High	Alligator cracking, weathering/raveling, stripping, T/L cracking, rutting		
HMA Overlay (<2 in)	Low			
	Medium		Alligator cracking, weathering/raveling, stripping, T/L cracking, rutting, bleeding, corrugation, potholes, patching, edge cracking	
	High			
Milling and Overlay	Low			
	Medium			Stripping, rutting, corrugation
	High			Weathering/raveling, stripping, rutting, bleeding, corrugation, water seepage
Cold or Mechanized Patch, or Base Repair	Low			Potholes
	Medium			Potholes, patching
	High			Potholes, T/L cracking, edge cracking
Bituminous Fill	Low	Potholes		
	Medium			
	High			

Table 46. Penn DOT Survey – Pavement Distress Addressed by Preventive Maintenance Treatments (Districts 4, 5, and 6)

Treatment	Distress Severity	PennDOT District		
		4-0	5-0	6-0
Crack Seal	Low			Alligator cracking, T/L cracking
	Medium	T/L cracking		T/L cracking
	High			
Polymer-modified HMA Overlay (2 in)	Low		Rutting	
	Medium			Alligator cracking, rutting, corrugation
	High			Alligator cracking, weathering/raveling, T/L cracking, rutting, corrugation, patching
HMA Overlay (<2 in)	Low		Alligator cracking, weathering/raveling, stripping, T/L cracking, patching, edge cracking	
	Medium	Alligator cracking		
	High	Weathering/raveling, patching		
Milling and Overlay	Low			
	Medium	Rutting, corrugation	Weathering/raveling	Alligator cracking
	High	Rutting, corrugation, bleeding		Alligator cracking, weathering/raveling
Cold or Mechanized Patch, or Base Repair	Low		Potholes	Potholes
	Medium	Potholes		
	High			

Table 47. Penn DOT Survey – Pavement Distress Addressed by Preventive Maintenance Treatments (Districts 8, 9, and 10)

Treatment	Distress Severity	PennDOT District 8-0	PennDOT District 9-0	PennDOT District 10-0
Crack Seal	Low	Alligator cracking, T/L cracking, edge cracking	Low severity only: Alligator cracking, T/L cracking, edge cracking	Alligator cracking, edge cracking
	Medium			
Chip Seal	Low	Potholes	Alligator cracking, weathering/raveling, T/L cracking, edge cracking	
	Medium			
	High			
Seal Coat	Low			Weathering/raveling
	Medium			Weathering/raveling, bleeding
	High			T/L cracking
Sand Seal	Low		Bleeding	Bleeding
	Medium			
Microsurfacing	High			Bleeding
Polymer-modified HMA Overlay (2 in)	High		Alligator cracking, weathering/raveling, T/L cracking, stripping, rutting, corrugation, edge cracking	Rutting
HMA Overlay (<2 in)	Low		Rutting, corrugation, potholes	
	Medium	Weathering/raveling, patching	Alligator cracking, weathering/raveling, T/L cracking, stripping, corrugation, potholes, patching, edge cracking	
	High	Alligator cracking, weathering/raveling		Weathering/raveling, T/L cracking, rutting, bleeding
HMA Overlay (>2 in)	Medium	Stripping, corrugation		
	High	Stripping, corrugation, edge cracking	Alligator cracking, weathering/raveling, T/L cracking, stripping, rutting, corrugation, bleeding, potholes, patching, edge cracking	
Milling and Overlay	Low			T/L cracking
	Medium	Bleeding	Rutting	T/L cracking, stripping
	High	Weathering/raveling, rutting, bleeding	Alligator cracking, rutting	Stripping, corrugation, patching
Cold or Mechanized Patch, or Base Repair	High			Alligator cracking, potholes

Table 48. Penn DOT Survey – Pavement Distress Addressed by Preventive Maintenance Treatments (Districts 11, and 12)

Treatment	Distress Severity	PennDOT District	
		11-0	12-0
Crack Seal	Low	T/L cracking, edge cracking	Edge cracking
	Medium	Alligator cracking, T/L cracking, edge cracking	Alligator cracking, T/L cracking
	High		Potholes
Chip Seal	Medium		Alligator cracking, weathering/raveling, edge cracking
Seal Coat	Medium		Weathering/raveling, stripping
Microsurfacing	Medium High	Bleeding	Rutting
Polymer-modified HMA Overlay (2 in)	High	Alligator cracking, weathering/raveling, T/L cracking, stripping, corrugation, rutting, potholes, patching, edge cracking	
HMA Overlay (<2 in)	Medium		Corrugation, bleeding, patching
HMA Overlay (>2 in)	Medium		Stripping
	High	Alligator cracking, weathering/raveling, T/L cracking, stripping, corrugation, rutting, potholes, patching, edge cracking	Weathering/raveling, stripping, corrugation, rutting, bleeding, edge cracking
Milling and Overlay	High	T/L cracking	Alligator cracking, weathering/raveling, T/L cracking, corrugation, rutting, patching, edge cracking
Cold or Mechanized Patch, or Base Repair	Medium		Potholes
	High		

PENNSYLVANIA DISTRICT SURVEY QUESTIONNAIRE (BLANK)

2009

PennDOT Preventive Maintenance Survey

Dear District / Pavement Engineer:

Under the Penn DOT's Project 070507, *Bituminous Overlay Strategies for Preventative Maintenance on Interstate Roadways*, a team of researchers from Applied Pavement Technology, Inc. and University of Pittsburgh is examining best practices for preventive maintenance of bituminous surfaces, both around the country and in Pennsylvania.

This survey has been developed and is being distributed to assess current practices among the various Penn DOT Districts. The questions relate specifically to the application of treatments to Penn DOT's bituminous-surfaced Interstate pavements. The results will be used to document local practices. Please note that one of our objectives is to identify and document actual practice. Space is provided at the end to add explanatory comments if desired.

Your help in completing and returning the survey by **February 6, 2009**, is greatly appreciated. A glossary of terms used in this survey is provided at the end. If you have any questions regarding the content of this survey or the purpose of this project, please feel free to contact any of the following:

Sincerely,

J. Michael Long, P.E.
Chief, Roadway Management
PA Department of Transportation
Bureau of Maintenance and Operations
johlong@state.pa.us
(717) 787-1199

David Peshkin, P.E.
Applied Pavement Technology, Inc.
(217) 398-3977
dpeshkin@appliedpavement.com

Dr. Amir Koubaa, Ph.D.
Academic Coordinator,
University of Pittsburgh
Department of Civil & Environmental Engineering
949 Benedum Hall
Pittsburgh, PA 15261
(412) 624-9869
(412) 624-0135 (Fax)
amk59@pitt.edu

Please return completed surveys to Dr. Amir Koubaa at the address above. Thank you.

SURVEY

1. For the given pavement distress and severity level, please indicate which treatments your District uses. Treatments are summarized in a list below, but feel free to identify other treatments not listed. If a hot-mix asphalt (HMA) overlay is used instead of one of the identified treatments, please indicate the typical HMA overlay thickness in the "Thickness" column.

Please select the treatment alternatives from the list given below:

Crack Seal, Fog Seal, Rejuvenator, Sand Seal, Chip Seal, Double Chip Seal, Slurry Seal, Microsurfacing, Cape Seal, Thin (< 2 inches) HMA Overlay, Thick (≥ 2 inches) HMA Overlay, Open-Graded Friction Course, Rubberized Asphalt Chip Seal, Polymer-Modified HMA Overlay, Cold In-Place Recycling, Other (please specify).

Pavement Distress and Severity		**Treatment**	**Thickness (if overlaid)**	**Comments**
Alligator Cracking	Low Severity			
	Medium Severity			
	High Severity			
Weathering and Raveling	Low Severity			
	Medium Severity			
	High Severity			

Pavement Distress and Severity		Treatment	Thickness (if overlaid)	Comments
Transverse and Longitudinal Cracking	Low Severity			
	Medium Severity			
	High Severity			
Rutting	Low Severity			
	Medium Severity			
	High Severity			
Potholes	Low Severity			
	Medium Severity			
	High Severity			

Pavement Distress and Its Severity		Treatment	Thickness (if overlaid)	Comments
Corrugations	Low Severity			
	Medium Severity			
	High Severity			
Patching	Low Severity			
	Medium Severity			
	High Severity			
Bleeding	Low Severity			
	Medium Severity			
	High Severity			

Pavement Distress and Its Severity		Treatment	Thickness (if overlaid)	Comments
Edge Cracking	Low Severity			
	Medium Severity			
	High Severity			
Stripping	Low Severity			
	Medium Severity			
	High Severity			
Other (Please list)	Low Severity			
	Medium Severity			
	High Severity			
Other (Please list)	Low Severity			
	Medium Severity			
	High Severity			

2. For each of the various pavement distresses, please identify the repairs that are made to the pavement when these distresses are present, prior to the placement of an HMA overlay on interstate pavements. If appropriate, in the "Comments" column identify the HMA overlay thicknesses to which these repairs are appropriate.

Pavement Distress	**If Applicable, Pre-Overlay Repair**									Comments
	Crack Seal	Chip Seal	Partial-Depth Patch	Full-Depth Patch	Milling	Leveling Course	Joint Sealing	Other (Identify)	Other (Identify)	
Alligator Cracking										
Weathering and Raveling										
Transverse and Longitudinal cracking										
Rutting										
Potholes										
Corrugations										
Patching										
Bleeding										
Edge Cracking										

Pavement Distress	**If Applicable, Pre-Overlay Repair**									Comments
	Crack Seal	Chip Seal	Partial-Depth Patch	Full-Depth Patch	Milling	Leveling Course	Joint Sealing	Others (Identify)	Others (Identify)	
Stripping										
Other Distresses (Identify)										
Other Distresses (Identify)										
Other Distresses (Identify)										

3. Please identify either your District's defined ranges or practice in classifying traffic on Interstate pavements as Low, Medium, and High by providing the Average Daily Traffic (ADT) and Average Daily Truck Traffic (ADTT).

ADT Classification	**Traffic Range**
Low	
Medium	
High	

ADTT Classification	**Truck Range**
Low	
Medium	
High	

For the treatments used in your District at different traffic levels, please identify the average expected service life and the traffic conditions under which the treatment is performed.

Type of Treatment	**Traffic Level**	**Indicate Measure Used: ADT or ADTT**	**Expected Service Life After Treatment (in Years)**	**Comments (restrictions, recommendations, etc.)**
Crack Seal	Low			
	Medium			
	High			
Fog Seal	Low			
	Medium			
	High			
Rejuvenator	Low			
	Medium			
	High			

Type of Treatment	Traffic Level	Indicate Measure Used: ADT or ADTT	Expected Service Life After Treatment (in Years)	Comments (restrictions, recommendations, etc.)
Sand Sealing	Low			
	Medium			
	High			
Chip Sealing	Low			
	Medium			
	High			
Double Chip Seal	Low			
	Medium			
	High			
Open-Graded Friction Course	Low			
	Medium			
	High			
Rubberized Asphalt Chip Seal	Low			
	Medium			
	High			
Slurry Seal	Low			
	Medium			
	High			

Type of Treatment	Traffic Level	Indicate Measure Used: ADT or ADTT	Expected Service Life After Treatment (in Years)	Comments (restrictions, recommendations, etc.)
Microsurfacing	Low			
	Medium			
	High			
Cape Seal	Low			
	Medium			
	High			
Polymer Modified HMA Overlay	Low			
	Medium			
	High			
HMA Overlay (less than 2 inches)	Low			
	Medium			
	High			
HMA Overlay (greater than 2 inches)	Low			
	Medium			
	High			
Cold In Place Recycling	Low			
	Medium			
	High			
Other Methods	Low			
	Medium			
	High			

4. Please indicate the average annual minimum and maximum temperatures (Fahrenheit) in your District:
   - Minimum = __________
   - Maximum = __________

For the different treatments listed please note the appropriate range of temperatures in which you use the treatment as well as the allowable range of pavement temperature. Please leave blank if your District does not use the treatment.

Type of Treatment	**Application Temperature**		**Pavement Temperature**		**Comments**
	Minimum	**Maximum**	**Minimum**	**Maximum**	
Crack Seal					
Fog Seal					
Rejuvenator					
Sand Seal					
Chip Seal					
Double Chip Seal					

Type of Treatment	Application Temperature		Pavement Temperature		Comments
	Minimum	Maximum	Minimum	Maximum	
Slurry Seal					
Microsurfacing					
Cape Seal					
Open-Graded Friction Course					
Rubberized Asphalt Chip Seal					
Polymer modified HMA Overlay					
HMA Overlay (less than 2 inches)					
HMA Overlay (greater than 2 inches)					
Cold In Place Recycling					
Other methods					
Other methods					
Other methods					

5. For the listed treatments, provide the range of pavement performance values in which you use the treatment. If you do not use the performance measure leave the cell blank. In the last column, indicate for your District whether the acceptable values identified in the columns to the left represent the treatment's use as preventive maintenance. In addition to the guidelines incorporated in PennDOT Publication 242, consider that preventive maintenance is widely thought of as the application of non-structural treatments to pavements that are in good condition.

	RANGE OF ACCEPTABLE VALUES FOR TREATMENT USE				**Acceptable Values Represent a Preventive Maintenance Application?**
Type of Treatment	**Pavement Serviceability Index**	**International Roughness Index**	**Pavement Serviceability Rating**	**Other Rating Indices**	
Crack Sealing					Y / N
Fog Seal					Y / N
Rejuvenation					Y / N
Seal Coating					Y / N
Sand Sealing					Y / N
Double Chip Seal					Y / N
Open Graded Friction Course					Y / N
Rubberized Asphalt Chip Seal					Y / N
Slurry Seal					Y / N
Cape Seal					Y / N
Microsurfacing					Y / N
Polymer Modified HMA Overlay					Y / N
HMA Overlay (less than 2 inches)					Y / N
HMA Overlay (greater than 2 inches)					Y / N
Cold In Place Recycling					Y / N
Other Methods					Y / N
Other Methods					Y / N

6. For the treatments used in your District, please rank the frequency of their use (where “1” is most frequently used, “2” next most commonly used, “3” sometimes used, “4” rarely used, and “5” never used), and effectiveness (defined as meeting or exceeding expectations for treatment life and extending the life of the pavement, where “1” is most effective, “2” is second most effective, “3” somewhat effective, “4” least effective, and “5” not effective).

Pavement Treatment	**Frequency Ranking**	**Effectiveness Ranking**
Crack Seal		
Fog Seal		
Rejuvenator		
Sand Seal		
Chip Seal		
Double Chip Seal		
Slurry Seal		
Microsurfacing		
Open-Graded Friction Course		
Rubberized Asphalt Chip Seal		
Cape Seal		
Polymer Modified HMA Overlay		
HMA Overlay (less than 2 inches)		
HMA Overlay (greater than 2 inches)		
Cold In Place Recycling		
Other Method		
Other Method		
Other Method		

7. Please provide additional information about preventive maintenance project selection, treatment selection, performance, and so on for your District.

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